The Glasgow Naturalist

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With Proceedings of the River Kelvin Conference

Glasgow Natural History Society

(formerly The Andersonian Naturalists of Glasgow)

The Glasgow Natural History Society is a registered charity (SC012586) with approximately 250 members living in Glasgow, the West of Scotland, throughout the UK and overseas. The Society arranges a full programme of events throughout the year in Glasgow and district and occasionally further afield. These are at both specialist and popular level, designed to bring together the amateur and the professional, the expert and the beginner. The Society has its own library, and provides grants for the study of natural history. Further details about the Society can be found at www.gnhs.org.uk or by contacting the Secretary, The Glasgow Natural History Society, c/o Graham Kerr (Zoology) Building, University of Glasgow, Glasgow, G12 8QQ, Scotland (E-mail: info@gnhs.org.uk). The Society has microscopes and some field equipment that can be used by members. Please contact the Membership Secretary Mr Richard Weddle at the address above for further details.

The Glasgow Naturalist

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Advice to contributors is given on the inside cover of this edition and at www.glasgownaturalhistory.org.uk/documents/gn advice.pdf. The publication is included in the abstracting and indexing of the Bioscience Information Service of Biological Abstracts and the Botanical Society of the British Isles Abstracts. Back numbers of the journal may be purchased by contacting the Society at the address above. Full details of the journal can be found at www.gnhs.org.uk/gnat.html

Publications of the Glasgow Natural History Society

The Society has published a number of books on the flora and fauna of the West of Scotland. Full details can be found at www.gnhs.org.uk/publications.html

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Common Kingfisher *Alcedo atthis*, River Kelvin, Kelvinbridge, Glasgow. Photo credit: Pete Murray (2017)
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Back Cover

River Kelvin, Kelvingrove Park, Photo credit: Keith Watson

The Glasgow Naturalist

Volume 26 Part 4

Edited by: Dominic J. McCafferty & Iain Wilkie

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EDITORIAL

A new era for scientific natural history

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One of the great benefits of our digital age has been the increased accessibility of knowledge. This is certainly true in natural history. I have seen *The Glasgow Naturalist* grow from a printed volume available to members and a number libraries to an online (and print) journal available to naturalists in Scotland and throughout the World. This period has also seen natural history as a discipline continue to flourish because of increased exposure in the media and from the growth in citizen science, which has harnessed the collective endeavours of naturalists for biodiversity recording and conservation efforts.

Dissemination of natural history knowledge is required not only for the success of citizen science projects but also as source of information for future scientific research and nature conservation. Natural history writing is no longer confined to dusty volumes in hidden shelves of the library: it is increasingly reaching greater prominence in our scientific journals. For example, the *American Naturalist* (AN, 2018) has reinstated 'Natural History Miscellany', first published from 1867 to 1872. These are "...short contributions (similar to a Note in length) that enlighten our understanding of the natural history of a species in important ways and, because of their novelty, will be appreciated broadly". Another development has been that the Ecological Society of America (ESA) has recently introduced a new submission category called 'Scientific Naturalist' in their flagship journal *Ecology* (ESA, 2018). This category is "...intended to attract a wide audience by showcasing the natural history of particular organisms (their morphology and behavior, their life histories, their habitats, and their roles in food webs and ecosystems). The writing should be of high quality to appeal to both a scientific as well as an educated, non-scientific audience." Closer to home we have a number of established journals, *The Glasgow Naturalist* being of them that allow naturalists to publish articles on noteworthy observations (e.g. *Scottish Birds, Bulletin of the British Lichen Society*).

These publishing developments highlight the contemporary value of scientific natural history, allowing new discoveries to reach a wide audience and contribute to our current knowledge and understanding of biology. Indeed, Callaghan *et al.* (In press) argue that today naturalists have a very important role to play in describing how organisms may be responding to increasing anthropogenic pressure. These authors therefore suggest that naturalists such as ornithologists can have the greatest impact in their field by carefully documenting 'unnatural history': "...the often opportunistic observation and description of avifauna placed in the context of a rapidly altered and changing world, and their adaptive or maladaptive behaviours, generally at an individual level. This could include innovative behavioural adaptations, novel diet choices, hybridisation, phenological changes in response to a warming climate, non-native species' interactions with native species, and novel adaptations to urbanisation."

Clearly, writing natural history articles is therefore of great value to the scientific community and the wider public, particularly to document anthropogenic change. However, it is also invaluable for the individual naturalist. A high quality peer reviewed published article can help to establish or verify a naturalist's credentials. Their expertise is seen to be valued and knowledge can be shared with a wider community of naturalists. This is particularly important at early stages of development as a naturalist or for biologists as they develop their career.

So what can we do to ensure that scientific natural history publication continues to thrive here in Scotland? The Glasgow Natural History Society (GNHS) has been publishing *The Glasgow Naturalist* since 1908 and in recent years has incorporated many of the features of commercial publishers by online publication of articles prior to print publication, including electronic supplementary material, and printing in full colour. All previous issues are now made available through the

Biodiversity Heritage Library (BHL, 2018) giving free access to this valuable resource. These digital developments are essential to the future success of the journal but what remains fundamental to its scientific credibility is the fact that well established and modern scientific techniques are peer reviewed by experts in their field. We are fortunate that the journal is well supported by dedicated reviewers, ensuring that the latest scientific knowledge is shared. The future of the journal however relies on recruitment of the next generation of scientific naturalists and to encourage this we award an annual new author prize (see details in the website: GNHS, 2018). Close links between GNHS and the University of Glasgow are also fundamental in supporting biology students to publish papers from undergraduate and postgraduate dissertations. To measure the impact of scientific publications, publishers are increasingly using Altmetric scores, which are based on the extent to which articles are reported in news outlets and social media. I would expect that social media will also play an important role to promote our journal in the future.

We therefore live in promising times for natural history. Publishing peer reviewed scientific natural history articles will be of great benefit to you, the scientific community and enhance scientific knowledge of the wider community. I therefore encourage you all to write in 2018.

ACKNOWLEDGEMENTS

The Glasgow Naturalist would not be produced without the hard work of many people, including the many anonymous reviewers who ensure the scientific quality of this journal. I am particularly grateful to Iain Wilkie as Editor of Short Notes and his continued help and enthusiasm, Anthony Payne for book reviews and to Richard Weddle for making journal articles available online. Thanks to Chris McInerny for facilitating the digitisation of the journal. Many thanks to Ruth Maclachlan who undertook copy editing and administrative duties. I will now be standing down as Editor, to take up position as Editor in Chief of *Ibis*. I have thoroughly enjoyed corresponding with authors and reviewers over the past 10 years to produce Volumes 24-25 and a number of conference proceedings. I am particularly indebted to the great help given to me by many people in this time, including Roger Downie and Geoff Hancock for editorial advice, Bob Gray for book reviews, both Norman Tait and David Palmar for photography and image editing. June Allardyce and Ruth Maclachlan provided all the support that a bigger team of copy editors and journal managers would normally provide, to whom I am very grateful. Finally I thank Iain Wilkie for all his good council and wish him well in now taking on the position of Editor.

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PROCEEDINGS OF THE KELVIN CONFERENCE

The River Kelvin; History and Natural history

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INTRODUCTION

This one day conference, organised by the Kelvin Biodiversity Network (principally comprising representatives of Glasgow Natural History Society, Friends of the River Kelvin, the Royal Society for the Protection of Birds, the Clyde River Foundation and The Conservation Volunteers) took place in the Graham Kerr Building, University of Glasgow on 6th June 2015, as a contribution to the 2015 Glasgow Science Festival. The meeting was well attended and included lively discussions. As a follow-up, the GNHS excursion programme included three events: a medicinal plants hunt in Kelvingrove Park, organised by the RSPB; a Bioblitz in Kelvingrove Park, also organised by the RSPB; and a walk from Summerston to Balmore, organised by FORK. In addition to the Abstracts of the talks presented, these proceedings include written-up and updated versions of the talks (marked * below), provided by some but not all of the speakers. We are grateful to all who were able to do this.

ABSTRACTS of PRESENTATIONS

Welcome and Introduction

Roger Downie (President, Glasgow Natural History Society) and **Sally Johnson** (Chair, Friends of the River Kelvin)

Origins of the Kelvin Biodiversity Network for which the conference is the first output. The conference is intended partly as a celebration of the river; its history, its biodiversity and its potential as a resource for the people of Glasgow. But also as an opportunity to discuss how the river could be improved and what threats it faces.

The River Kelvin: route and resource from pre-history to the 20th century*

John Hume (John lectured in industrial and economic history at the University of Strathclyde 1964-84, then worked for Historic Scotland until 1999. He has a particular interest in the industries of the West of Scotland, especially those of the Clyde and Kelvin)

In this presentation, I will look first at the role of the Kelvin and its valley in relation to transport and com munications in west central Scotland. The main body of the talk will be an examination of the river as a source of water-power and process water for a wide range of industries, from the Middle Ages to the later 20th century.

Glasgow's biodiversity: the importance of the Kelvin corridor*

Cath Scott (Natural Environment Officer: Biodiversity and Ecology, Land and Environmental Services, Glasgow City Council)

Glasgow's Local Biodiversity Action Plan was launched in 2001 to protect and enhance habitats and species, and raise awareness of the importance of the natural heritage. Glasgow is rich in biodiversity, which is protected through an extensive green network of designated sites including Sites of Special Scientific Interest, Local Nature Reserves, Sites of Importance for Nature Conservation and Green Corridors. Nationally and locally important habitats and species can be found in the urban environment. Partnership projects have delivered key targets for management, restoration and creation of wetland, woodland and grassland habitats. The River Kelvin is a well-loved major wildlife corridor in Glasgow connecting people to nature and forming the framework of the green network.

Are we caring for the Kelvin? Biodiversity research and public engagement

Willie Yeomans (Clyde River Foundation)

The Clyde River Foundation (CRF) is a local charity which researches the ecology of the Clyde and its tributaries and promotes environmental education and community engagement throughout the catchment. The Kelvin sub-catchment represents approximately 12% of the total Clyde system river length. The Kelvin is recovering ecologically from more than a century of man-made pollution and physical change. Since 2002, the CRF has monitored the fish and invertebrate communities and species at key sites to generate long-term data sets and to investigate specific management issues. Other scientific work has included fish habitat surveys of the main tributaries; assessing effects of flood defence and land drainage on channel sinuosity; and mapping the occurrence of invasive, non-native riparian plants. CRF education programmes have worked from P3 to PhD levels across the Kelvin system and we reconnect people of all ages with the river to improve environmental stewardship. Recently, we have developed community engagement projects in close collaboration with the River Kelvin Angling Association and the residents of

Twechar, in the upper catchment. This paper will provide a brief overview of previous, ongoing and planned CRF work in and around the Kelvin, and ask whether we are taking sufficient care of 'Glasgow's second river'.

The changing flora of the Kelvin*
Keith Watson (Curator of Natural History, Glasgow Museums)
Reviewing historical records from herbarium specimens and old literature, and comparing with the many modern field records, readily reveals that the riparian flora of the Kelvin is constantly changing. Much of this is in response to the actions of humans over the last 150 years or so. Many years of engineering, landform changes and pollution, in addition to changing attitudes to bankside land management, have dramatically altered the habitat that the current flora has inherited. A few native species are long gone but many are still present, but the abundance and diversity of non-native species is now an obvious feature of the lower urban stretches. Is this change in species composition a negative development and should we be trying to put the clock back to a previous time? Or should we be celebrating the floral diversity that we now find and admire the dynamic nature of our ever changing flora?

Connecting people to the Kelvin; celebrating and enhancing our city's wildlife
Katherine Jones (Public affairs manager, SW Scotland region, RSPB Scotland)
The River Kelvin offers a fantastic opportunity for people to connect with nature in the heart of the city. Winding through some of Glasgow's most deprived communities, as well as the more well-heeled West End, the river lays down the challenge to us of how to engage more people, from a wider audience, with our city's wildlife. RSPB research has shown that children play out in nature less than ever before, which is creating a generation disconnected from nature, and this talk will explore some of the work that RSPB Scotland, alongside our many local partners, is doing around the river Kelvin to start to turn this trend around.

Power from the Kelvin: past and future*
Neil Phillips (Sustainable energy consultant)
As many as ten mills have used the water-power of the Kelvin within the current city boundary in the past, and the weirs which maintained a head of water are still in place. Given the overall policy to increase Scotland's usage of renewable energy sources, the talk will discuss the economic viability and practical prospects of harnessing the Kelvin's energy for modern purposes.

How the Kelvin makes a great place
Gillian Dick (Glasgow City Council, Place Strategy and Environmental Infrastructure)
This talk will outline the City's emerging development plan and its placemaking policy. It will discuss how the environment of the Kelvin contributes to a great place.

Discussion session*
A set of facilitated small group discussions on the issues facing the Kelvin and how they can be addressed. This paper provides the discussion topics, but not the contributions made by participants.

In addition
The conference also included a poster display and a picture quiz. A version of the poster prepared by Kate Arnold and colleagues (SEPA) on 'Ecological monitoring of the lower Kelvin, 1979-2014'* is included in these proceedings.

The River Kelvin: route and resource from pre-history to the 20th century

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INTRODUCTION
The River Kelvin is not a large stream except in times of spate, but it is the largest tributary of the Clyde in the vicinity of Glasgow, and as such was for many centuries a significant location for water-powered and water-using industries connected with that settlement. Its valley narrows to a gorge in several places, so that sites for large industries were restricted; on the other hand, the concentration of the flow at these points made the construction of weirs to impound water easier and more effective.

The Kelvin rises in the central rift valley in the neighbourhood of Kilsyth, and flows west and then south, entering the Clyde opposite Govan. It is generally a slow-flowing river, except in its last fall at Partick, where a ridge of hard rock creates a natural weir. This proved an effective site for water-mills, and up-stream artificial weirs were built at several points. Some of the millsteads thus created were probably used from early historic times. Another use of the waters of the Kelvin was to feed the summit level of the Forth and Clyde Canal. Its construction, from 1768, involved diverting some of the headwaters of the river into Townhead Reservoir, near Banton, east of Kilsyth. Mill-owners were inevitably concerned about the effect this would have on their operations, and legal action resulted in an agreement regarding compensation water.

Apart from the uses of the water of the Kelvin for generating water-power, and to supply the canal, it was also used for boiler and condensing water for steam engines, and for process water, especially in paper-making and calico printing, and for the disposal of liquid waste (including human excrement). Despite growing levels of pollution, the section of the river from Kelvindale to Kelvingrove, where it flows through a succession of gorges, was much appreciated for its scenic beauty. At Kelvingrove the widening of the valley created an area which, when landscaped, formed excellent pleasure grounds. These were important in making the Park area a select and architecturally-refined suburb of the growing city. Kelvingrove Park was also used as the setting for the city's three major exhibitions in the years before the First World War, in 1888, 1901 and 1911. Finally, in the last, tidal, section of the river, at Partick, it was used as water-space for shipbuilding and ship-repair, from the 1840s to the 1960s. In addition to these water-using functions, the river valley, in some sections, provided useful transport routes, some used by riverside industries, though strictly this falls outside the scope of this paper, the rest of which deals thematically with the different classes of use identified above.

Power

Over the centuries the most important use of the river for power was for grain milling. The Vitruvian (vertical) waterwheel was invented in Roman times, but it appears that it was introduced into Britain on a significant scale with the advent of the feudal system in the 11th-12th century, with the accompanying concentration of control of the people in the hands of the landowners. The construction of relatively large water-powered mills, which the tenantry were obliged to use, was a characteristic aspect of feudalism. To generate enough power for these mills vertical wheels were essential, as were good millsteads. The millsteads of Partick were excellent in this respect. The Bunhouse Mills (Fig. 1) and the Bishop's Mills (Fig. 2) were probably the oldest, as they appear to have been well-established when the Bunhouse Mills were granted in the 1560s to the Incorporation of Bakers in Glasgow. Other mills in and around Partick, which followed, were the Scotstoun Mills (Fig. 3, the only ones in the village), the Clayslaps Mills (Fig. 5), and the Slit Mills (Fig. 6), originally built for making iron nail- rod, which used an extension of the Bishop's Mills lade for its water-supply. Also within the present Glasgow boundary were the Garrioch and North Woodside mills, and possibly the first South Woodside mills. The Bunhouse and Clayslaps mills produced flour, probably from imported wheat, while the others were oatmeal mills. The Garrioch, North Woodside (and possibly the South Woodside) mills had gone out of production by the mid-19th century, and the site of the Garrioch Mills was incorporated into the landscaping of the north bank of the river in the 1870s. In the later 19th century the technique of roller milling eliminated the older one of stone grinding, for flour production; the Clayslaps Mills were abandoned and the Bunhouse Mills were sold and replaced by the Regent Mills (Fig. 7). The Scotstoun Mills were similarly redeveloped for roller milling (Fig. 4). This complex also produced milled products for feeding horses and cattle, and the Bishop's Mills, too, concentrated on that side of the business. The Regent Mills were acquired in 1910 by the Scottish Co-operative Wholesale Society, and continued to make their 'Lofty Peak' flour until about 1960. Both it and the Bishop's Mills continued to use some water-power into the 20th century. The Slit Mills disappeared when the Stobcross Branch of the North British Railway was constructed in the 1860s. The millstead of South Woodside was used for the construction of a water-powered cotton-spinning mill, the first such mill in Glasgow (Fig. 8). The water supply from the Kelvin was barely adequate to power it, and it did not long survive the introduction of steam-powered cotton mills. It was supplanted by a power-loom cotton weaving factory, which probably used river water for its steam engine (see below).

Fig. 1. Bunhouse Mills c1840 (Incorporation of Bakers).

Fig. 2. Bishop's Mills c1966 (author's photograph).

Fig. 3. Scotstoun Mills early 19th century (Napier, 1873).

Fig. 4. Scotstoun Mills c1966 (author's photograph).

Fig. 5. Clayslaps Mills c1840 (Anon., 1931).

Fig. 6. Slit Mills 1848 (Simpson, unpublished).

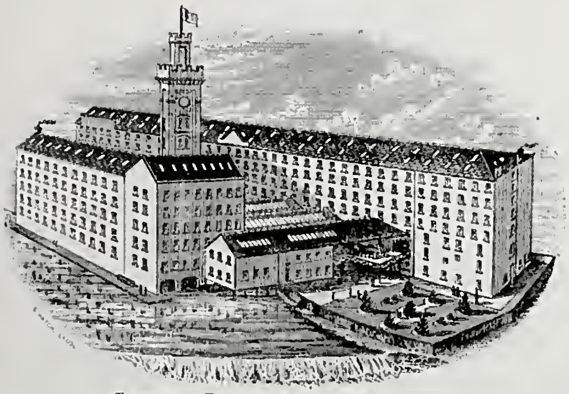

Fig. 7. Regent Mills c1890 (Stratten, 1891).

Fig. 8. South Woodside Cotton Mill c1900 (Glasgow Museums).

It is also worth mentioning that in the 18th century, at the Balgray Paper Mills (see below), there was also a snuff mill, in which the stalks of tobacco leaves were ground to make the fine powder which is the basis of snuff.

The last user of Kelvin water for power was the North Woodside Mills, rebuilt in 1846 as a flint-grinding mill (Fig. 9). It continued to be solely water-powered until it closed in about 1960. It had a central water wheel (Fig. 10) which drove rotating paddles in circular water-filled tubs which pushed blocks of chert over flint nodules which had been roasted (calcined) in a kiln. The chert wore away the nodules, producing a milky suspension of powdered flint. This was then dried to produce a paste, which was packed into barrels for transport to potteries, where it was used as a component of glazes.

Remains of weirs survive to remind us of lost mills. The most complete are the weirs for Kelvindale Paper Mills at Maryhill (Fig. 11), and of the North Woodside Mills, below the Queen Margaret Drive road bridge. The Bunhouse Weir (Figs. 12; 13), between the Kelvingrove Museum and Art Gallery and Glasgow University, is still largely intact, but only fragments remain of the Clayslaps Mills weir, just downstream from the Kelvin Way bridge. The remains of the South Woodside Mills weir (below the Great Western Road Bridge at Kelvinbridge) and the Scotstoun Mills weir's remains can be seen, when the river is low, below Partick Bridge.

Fig. 9. North Woodside Flint Mill c1930 (Glasgow City Archives).

Fig. 10. Wheel, North Woodside Flint Mill 1959 (John Shaw-Dunn).

Fig. 11. Weir, Kelvindale Paper Mills 1965 (author's photograph).

Fig. 12. Weir, Bunhouse Mills late 19th century (author's collection).

Fig. 13. Sluices Regent Mills c1970 (author's drawing).

Process Water

This term is used to describe water used in the making of something. Several of the industries on the Kelvin may reasonably be assumed to have used river water in the processes they carried on. Two of these industries certainly did: paper-making and calico-printing. There were two paper mills on the river within our area: Dalsholm, upstream from Maryhill, and Kelvindale (Fig. 14, also known as Balgray). The techniques used in paper-making changed in the 19th century, when hand paper-making was superseded by machinery, but as far as water is concerned the principle remained the same. A thin 'soup' of plant fibres, suspended in water known as 'stuff', was then spread thinly on a fine wire sieve, and the water was then removed either by gravity, or by suction. The resulting sheet of fibres was then dried to make paper. Both the Kelvin mills drew water from the river, filtered it, and then until the later 20th century returned the waste water to the river. This contained some fibrous material and if coloured paper was being made, water-soluble dyes. Paper-mill effluent fermented in its passage down-river, absorbing oxygen, making a foul smell, and rendering the river inhospitable to fish and other riverine life. The Dalsholm mill closed in the 1960s, and the Kelvindale mill in the late 1970s. Both have been demolished.

There were at least two, probably more, calico-printing works on the Kelvin in our area, at Maryhill (Figs. 15; 16) and Partick (Fig. 17). In both of these, filtered water would have been used to prepare cloth for printing and washing out excess dyestuffs and mordants (used to fix the dyes to the cloth) and bleaching agents. The contaminated water would have been returned to the river. The quantities would, however, have been much smaller than those produced by paper mills.

Fig. 14. Kelvindale Paper Mills 1930 (Glasgow City Archives).

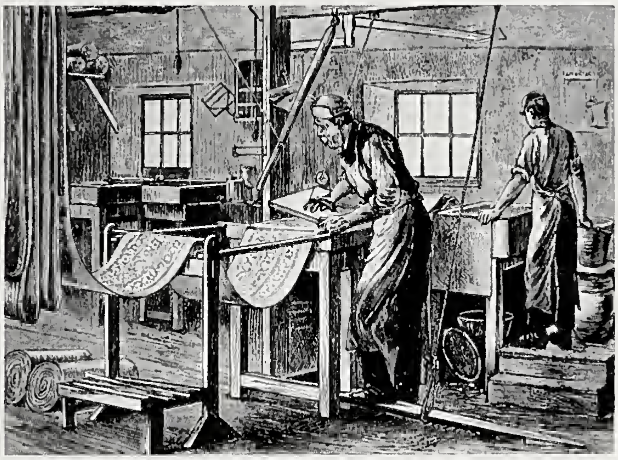

Fig. 15. Hand printing of calico late 19th century (author's collection).

Fig. 16. Former calico-printing works, Maryhill, 1966 (author's photograph).

Fig. 17. Partick Print Works mid-19th century (Napier, 1873).

The North Woodside Flint Mill (and probably the Garrioch Mill) used river water in the grinding process, and probably returned some to the river, containing a fine suspension of calcined flint (silicon dioxide).

Cooling and condensing

Other industries in the area used river water for cooling, notably the Dawsholm Gas Works. Smaller-scale users of river-water for cooling were concerns which used steam engines for power, including as well as the paper-mills and gas works the Bunhouse, Regent, Scotstoun and Bishop grain mills in Partick and the Partick Sewage Pumping Station (Fig. 18). In a river with such a small volume the heat pollution produced by this use could at times have been considerable.

Waste disposal

It is in the nature of rivers that they were until comparatively recent years used to dispose of human and animal excreta, and for surface-water drainage. The use of the 'Snow Bridge' (the first turnpike road bridge at Partick) to dispose of snow from the streets, contaminated with horse excrement, is an extreme case of such a practice. Apart from this very intermittent use the quantity of such material in most of the Kelvin was probably not great. In the tidal section of the river, below the first Partick Bridge, however, drainage from the village would have been supplemented by tidal influx of both industrial waste and sewage from Glasgow, and from vessels using the river.

Water space

The amenity use of the Kelvin in its course through Glasgow has been referred to above, as has the probable use for water-borne communication between the Clyde and the upper reaches of the river in prehistoric and early-historic times. This last section of my narrative is, however, dominated by the use of the tidal section of the river by shipbuilders and repairers. There were three of these, two on the west bank and one on the east. The first of these was the firm of Tod and MacGregor (Fig. 19), who started building iron ships on the west bank, on the angle between Kelvin and Clyde, in 1847. Immediately adjacent to their yard the firm of Thomas Seath built a few ships before Tod and MacGregor constructed a graving dock and a 'patent slip' for ship repair on the site of the Seath berths. On the east bank the firm of A. and J. Inglis (Fig. 20) established a similar business, from 1864, though they did not have a graving dock. Tod and MacGregor, their successors D. and W. Henderson, Thomas Seath and Co. and A. and J. Inglis all used this stretch of the Kelvin for launching and fitting out vessels, and for repairing and refitting ships. For these purposes the river was dredged most of the way up to the old Partick Bridge. There was also for a time in the 19th century a rowing-boat ferry across the mouth of the Kelvin.

Fig. 18. Partick Sewage Pumping Station c1966 (author's photograph).

Fig. 19. Tod and MacGregor's Shipyard 1860s (author's collection).

Fig. 20. A. and J. Inglis's Yard, Pointhouse c1950 (Glasgow City Archives).

CONCLUSION

This outline of the industrial uses of the Kelvin brings into focus their possible effects on the modern biology of the river. Though as recently as the 1960s it was seriously polluted by paper-making waste, such pollution is by its nature short-lived. There may be residues of calico-printing chemicals (heavy metal mordants) in silts in the littoral. Other possible contaminants are heavy metals leached from coal ash produced in riverside factories and in the steam locomotive depot at Dawsholm, but given the frequent spates this river experiences this is unlikely. It is possible that in the vicinity of Dawsholm Gas Works coal-tar residues may still exist. As a research exercise it might be worth sampling and analysing both river-bed (especially above weirs) and littoral silts.

ACKNOWLEDGEMENTS

I greatly appreciate the invitation from Professor J.R.Downie to take part in the Kelvin Biodiversity Conference and for his help and encouragement in preparing this paper for publication. I am most grateful to the staffs of the Mitchell Library, Glasgow City Archives, and Glasgow Museums and Art Galleries for help over many years, and for permission to reproduce material in their collections.

At a more personal level, I must thank my old friend Dr. John Shaw-Dunn for his photograph of the North Woodside Flint Mill (Fig. 10). Finally, in retrospect, I must mention John Robertson, dead these many years, whose enthusiasm for the Kelvin was inspirational.

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Glasgow's biodiversity: the importance of the Kelvin corridor

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ABSTRACT

Glasgow's Local Biodiversity Action Plan was launched in 2001 to protect and enhance habitats and species, and raise awareness of the importance of the natural heritage. Glasgow is rich in biodiversity, protected through an extensive green network of designated sites including Sites of Special Scientific Interest, Local Nature Reserves, Sites of Importance for Nature Conservation and Green Corridors. Nationally and locally important habitats and species can be found in the urban environment. Partnership projects have delivered key targets for management, restoration and creation of wetland, woodland and grassland habitats. The River Kelvin is a well-loved major wildlife corridor in Glasgow connecting people to nature and forming the framework of the green network.

ABBREVIATIONS

British Trust for Ornithology (BTO), Butterfly Conservation Scotland (BCS), Forestry Commission Scotland (FCS), Glasgow and Clyde Valley Green Network Partnership (GCVGNP), Glasgow City Council (GCC), Glasgow Natural History Society (GNHS), North Lanarkshire Council (NLC), Royal Society for the Protection of Birds (RSPB), Scottish Natural Heritage (SNH), Scottish Ornithologists' Club (SOC), Scottish Wildlife Trust (SWT), The Conservation Volunteers (TCV) and Woodland In and Around Town (WIAT).

Glasgow's Local Biodiversity Action Plan

Glasgow's Local Biodiversity Action Plan (LBAP) was launched in 2001 and is very much a partnership process (Glasgow's Biodiversity Partnership, 2001). The LBAP focuses on protection and enhancement of habitats and species, and awareness- raising. Over the years Habitat Action Plans (HAPs) and Species Action Plans (SAPs) have been produced. Since 2008 these are now grouped under the following broad habitats and/or categories:

Woodland: includes broad leaved and mixed woodland, and wet woodland HAPs. By protecting, managing and enhancing woodland, SAPs are

delivered through protecting the associated species including badger, bluebell, wood crane's-bill and toothwort.

Wetland: includes a wide range of habitats from raised bogs to ponds (raised bog, marsh, reedbeds, swamp, fen, wet woodland, standing open water, rivers and streams HAPs). By protecting, managing and enhancing wetland, SAPs are delivered through protecting the associated species which include water vole, otter, jack snipe, reed bunting, palmate newt, tufted loosestrife, common frog, common toad, Atlantic salmon, dragonflies and damselflies, bog-rosemary and bog-mosses.

Peatland restoration is highlighted as a national priority because of the many ecosystem services it provides including carbon sequestration and biodiversity (Scottish Government, 2015).

Grassland: includes acid grassland, neutral grassland and dwarf shrub heath HAPs. By protecting, managing and enhancing grasslands, SAPS are delivered through protecting the associated species which include skylark, small pearl-bordered fritillary, common frog, common toad, burnet-saxifrage and sheep's-bit.

Farmland: this does not spring to mind as a typical habitat in Glasgow but the urban fringes have large areas of farmland and agricultural grant schemes are a good opportunity to manage these areas positively for biodiversity and can deliver woodland, wetland and grassland actions.

Built up areas and gardens/awareness-raising: Engaging the public is particularly important in urban areas like Glasgow and is a large focus of the LBAP.

LBAP refresh

The LBAP is an on-going process and is being refreshed. The updated LBAP will focus on ecosystems to streamline action plans and focus resources to achieve maximum benefit for biodiversity.

A major aspect of this is the Biological Audit for the city because it is essential to know as much as possible about the biodiversity in the City and surrounding areas to assist with prioritising key habitats and species for action. Glasgow Museums have been working on a major update. The Audit is now (September, 2016) up to 6486 species and counting.

The LBAP refresh is an opportunity to include recent updates and discoveries. One example is water voles that no longer fit under the Wetland Habitat Action Plan.

Water vole update

In 2008, in response to a pest control query, water voles were discovered living away from water. Water voles living away from water are termed fossorial which means mole-like as they lead a more subterranean lifestyle. Since 2008 more and more sites have been discovered in the east end of Glasgow.

Research on these animals has been on-going as a collaboration between Glasgow City Council (GCC) and the University of Glasgow. In 2014 a grant-funded Masters by Research project was set up with GCC, University of Glasgow and Glasgow Natural History Society (GNHS) to carry out scientific research. The research found that the fossorial populations can occur at densities not seen before in the UK (Stewart, 2015). The unusual behaviour and population density means that Scottish Natural Heritage now consider this population to be of national significance (R.Raynor, pers.comm.). Glasgow's LBAP will be updated to reflect this unusual discovery.

Wildlife sites

The protection of biodiversity starts with the protection of sites. Sites of Special Scientific Interest (SSSIs), Local Nature Reserves (LNRs), Sites of Importance for Nature Conservation (SINCs), Green Corridors and parks amount to over 100 sites protected with environmental designations in the City Plan.

Habitat connectivity and integrated habitat networks are being recognised nationally as vital for biodiversity but this has always been recognised in Glasgow. All major watercourses in Glasgow are designated SINCs and major transport corridors are designated Green Corridors.

Glasgow Biodiversity Partnership Projects

The biodiversity process in Glasgow is very much a partnership process. Table 1 shows just a few examples of projects that have taken place in the city since the launch of the LBAP.

The River Kelvin corridor

Overview

Intact watercourses such as the River Kelvin are particularly important wildlife corridors in urban areas, especially as many others are fragmented due to historic land use changes and development.

Glasgow Museums manages the biological records for Glasgow which informs the Biological Audit which is the basis for the LBAP and the following statistics were generated using the River Kelvin SINC boundary. At least 2524 different species have been recorded in the River Kelvin corridor (River Corridor SINC and 500m buffer) within Glasgow. The biological audit for Glasgow now stands at 6486 species which amounts to the River Kelvin corridor having 39% of all the species found in Glasgow. Of these, 461 (7%) species are (in Glasgow terms) unique to the River Kelvin. It is not easy to interpret these statistics. Some of the unique species are not necessarily good news because for example one of them is the non-native signal crayfish. However, it is

safe to say that the large number of records is due to the recording efforts of many individuals, groups and organisations, which demonstrates the appeal of this iconic river.

Some of the biodiversity highlights of the river are otter, badger, bats (common and soprano pipistrelle, brown long-eared and Daubenton's), kingfisher and dipper. Atlantic salmon has been one of the success stories of the Clyde catchment. Salmon returned to the Clyde and the River Kelvin after being absent due to pollution. Improvements in water quality assisted their return. Otter have returned to sites formerly occupied, but are perhaps feeding on the salmon.

Project Title	Description	Key Biodiversity Target	Lead Organisations
Woodland partnership	FCS lease of GCC woodlands	Woodland HAPs and awareness	FCS and GCC
Woodland management	Woodland management and access improvements	Woodland HAPs	FCS and GCC (WIAT funded)
Seven Lochs Wetland Park	Landscape scale biodiversity, heritage and access project	Wetland HAPs awareness and access	FCS, GCC, GCVGNP, NLC, SNH and TCV
Glasgow's Living Waters	Pond creation and management & monitoring	Wetland HAPs	Buglife, Froglife and GCC
Cathkin Marsh	Wetland management and access	Wetland HAPs	GCC and SWT
Pond Naturalisation	Naturalisation of park ponds	Wetland HAPs	GCC
Commonhead Moss	Bog restoration project	Raised Bog HAP	GCC and SWT
Green Stimulus	Restoration of all GCC lowland raised bogs	Raised Bog HAP	FCS, GCC, GCVGNP, SNH and TCV
Meadow Trial Project	Meadow creation trials	Grassland HAPs	GCC and SNH
Glasgow's Buzzing	Meadow creation and management & monitoring	Grassland HAPs	Buglife and GCC
Farmland Birds	Habitat creation and management & monitoring	Farmland and awareness	GCC, RSPB, SOC and Starling Learning
Biodiversity In Glasgow (BIG)	Monitoring of birds and butterflies	All HAPs and awareness	BCS, BCS and GCC
Habitat Restoration Project	Habitat enhancement and management & awareness raising	All HAPs and awareness	GCC, SWT and TCV
Local Nature Reserves	Declaration and promotion of Local Nature Reserves	All HAPs and awareness	Friends' of Glasgow's LNRs, GCC and SNH
Giving Nature A Home	Habitat creation and management & awareness raising	All HAPs and awareness	RSPB Scotland and wide partnership
Biological Audit	Management and interpretation of biological data	All HAPs and SAPs	GCC, Glasgow Museums, GNHS and all of LBAP partnership
Fossorial Water Voles	Scientific research on Glasgow's non aquatic water voles	Water Vole SAP	GCC, GNHS, SNH and University of Glasgow
Eco Schools and Bird Friendly Schools	School grounds biodiversity projects	Urban and awareness	GCC and RSPB Scotland
Awareness raising	Large scale events such as BBC Springwatch , RSPB Wildlife Garden Festival, International Biodiversity Day, Pollok Family Day, Conferences and numerous engagement activities and events	Greenspace and awareness	LBAP partnership

Table 1. Glasgow Biodiversity Partnership projects.

Sites

The River Kelvin SINC: The SINC covers the full length of the River Kelvin in Glasgow and includes the river, bankside vegetation and associated sites. Habitat management and creation has been carried out by GCC in parks and greenspace adjoining the river (Figure 1).

Fig.1. Wildflower meadow creation at Kelvingrove park.

Millichen Flood SINC: This is privately owned farmland that is part of the natural floodplain of the river. Typical birds include thousands of geese in winter (mainly pink-footed goose and greylag goose), good numbers of wigeon and teal (when the Flood is flooded in winter) and passage waders (in autumn). Summer migrants include grasshopper warbler, willow warbler, whitethroat, swallow, sand martin and house martin. RSPB Scotland (Glasgow Group), Kelvin Clyde Greenspace and Starling Learning have previously carried out habitat enhancements and monitoring projects here for farmland birds including tree sparrow, reed bunting and yellowhammer.

Dawsholm Park LNR: This site is owned and managed by GCC. The main habitat is woodland. There are small areas of wildflower meadow as well as ponds and the river. Recent projects include woodland management which was carried out by GCC funded by a grant from Forestry Commission Scotland to diversify the age structure of the woodland and control rhododendron. New areas of woodland have been created and meadows enhanced as part of community events and Froglife created a new pond.

Recently the Friends of Glasgow's Local Nature Reserves (an NGO established in 2011) have carried out a lot of activities and events including guided walks, litter picks, installation of bird and bat boxes, and hedge planting. RSPB Scotland volunteers have been enhancing the meadows.

Botanic Gardens: This is a much more formal site with plant collections in the glasshouses and the famous Kibble Palace. However, general management of the Botanic Gardens incorporates biodiversity enhancements and the grounds include the River Kelvin. Recent projects include the creation and enhancement of wildflower meadows and in collaboration with the RSPB Scotland, the installation of a 'bug hotel'- a wall with crevices for a range of invertebrates to find shelter.

Kelvingrove Park: The River Kelvin is probably best known at Kelvingrove Park, as the central feature of the designed landscape of the park. BBC Breathing Places helped raise the profile of biodiversity and in 2007 a large BBC Springwatch event was held in the park, delivered by the Council, BBC and the LBAP partnership. Over 25,000 people attended. The event was not just about one day of activities it was about leaving a lasting legacy. Kelvingrove Park now has a naturalised pond, butterfly garden and wildflower meadow that are cared for at volunteer activities organised by GCC in partnership with RSPB Scotland, The Conservation Volunteers and GCC. Since 2007, Kelvingrove Park has been the location for Bioblitz days organised by the RSPB, attracting volunteers to record as much biodiversity as possible in a single day.

Biodiversity: the way forward

The LBAP refresh will focus resources to maximise biodiversity delivery within the City. Updated actions and objectives will provide new measurable targets. As part of its biodiversity duty GCC is committed to mainstreaming biodiversity into all its activities. Capacity building, in times of reduced resources, is key to effective project delivery. The LBAP process is an example of a successful partnership project. The aim is to continue with the existing partnership and to expand to develop new projects with a wider range of organisations to build capacity.

ACKNOWLEDGEMENTS

The Biological Audit is updated by many individuals, groups and organisations. Thanks go to GNHS, in particular the Changing Flora of Glasgow surveyors including the late Peter Macpherson, GCC Conservation and CRS, Glasgow Museums Biological Records Centre, Buglife for invertebrates including wildflower meadows, SEPA for aquatic invertebrates, Clyde & Argyll Fungus Group and

others too numerous to mention. Richard Weddle updated the records data for this article.

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The changing flora of the Kelvin

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When looking at the significance, conservation and management of the flora of a particular place one has to be aware of its past history as well as its current diversity. When the place is a dynamic stretch of a mostly urban river many factors come into play.

Historically one has to ask the question: what constitutes the flora at any particular moment in time? Assuming that some information with which to make an assessment is available, do we know if it has been like this for a long time? A brief review of literature, old paintings and images readily shows that there have been dramatic changes to the landscape along the River Kelvin, both rural and urban, and thus changes to the habitats. In Glasgow, the industrial revolution had a huge impact on the river as can be seen from the earliest maps to the present day; additionally there are numerous photographs from the twentieth century which graphically show built developments along the banks and often a lack of any suitable habitat for plants and animals.

However, in more recent times, certainly in urban areas, there has been some rewilding of many sections of the river. Abandoned structures have been colonised, and rubble has mixed with alluvial sands to create habitat niches along the river's margins. Initially colonised by ephemeral weeds and herbaceous perennials, scrub soon develops and semi-natural woodlands are now establishing throughout (locally enhanced by planting). Rural stretches have been affected by agricultural changes, and although some broad areas of relatively unimproved grassland occur along the old levees many are no longer grazed, resulting in dense tall herbs and scrub spread.

Water quality has also changed. Since the heavily polluted days of the 19th and early 20th century, much effort has been directed at cleaning up the water. The return of the salmon in the 1980s is testimony to the success of this work, supported by less showy survivors such as several pondweeds and floating bur-reed. However, although appearing much cleaner, agricultural improvements upstream result in high nutrient inputs to the water course.

Plants are good at recolonising past disturbed places, but current ground and water conditions are not the same as those previously encountered. This can affect which species can recolonise and, of great relevance to the urban context, there are many more non-native plants in the local area than was the case 200 years ago.

There are some 250 species of vascular plant that have been recorded along the Kelvin over recent times, and herbarium and literature sources indicate nearly half of these are named from the Kelvin in the 19th century (unfortunately, place names are seldom cited for common species). About 13 natives are now extinct (e.g. the oak fern collected in 1840 by William Gourlie: Fig.1) but the vast majority are still to be found, although not always in large populations; native woodland survivors include wood speedwell (Fig.2), ramsons, dog's mercury, wood stitchwort (Fig.3), wood melick, wood sedge, moschatel and bluebell.

However the old botanists would be surprised, if not shocked, by the many new arrivals that can be found along the riverbanks (Fig.4). Many non-natives have been around for a long time but quite a few have spread in more recent times, good examples being fringe-cups, pick-a-back-plant, summer snowflake (Fig.5) and few-flowered garlic, the latter now carpeting areas with its bright green, pungent leaves in early spring, but soon disappearing back underground before the summer. Some newcomers are strangely exotic such as skunk cabbage and purple toothwort; the former was known to be established near the Allander tributary in Milngavie but was later noted in the mud of the old weir at Kelvingrove in the 1990s. The toothwort has been known from the Glasgow Botanic Gardens since 1915 but has so far not spread any further. Some plants found are nationally quite rare such as the round-leaved saxifrage (Fig.6), which was collected from the Fin Glen catchment up in the Campsie Hills in 1924.

Fig.1. Oak fern, *Gymnocarpium dryopteris* collected by William Gourlie, 1840, Herb GL.

Fig.2. Wood speedwell, *Veronica montana*, native of old woodlands.

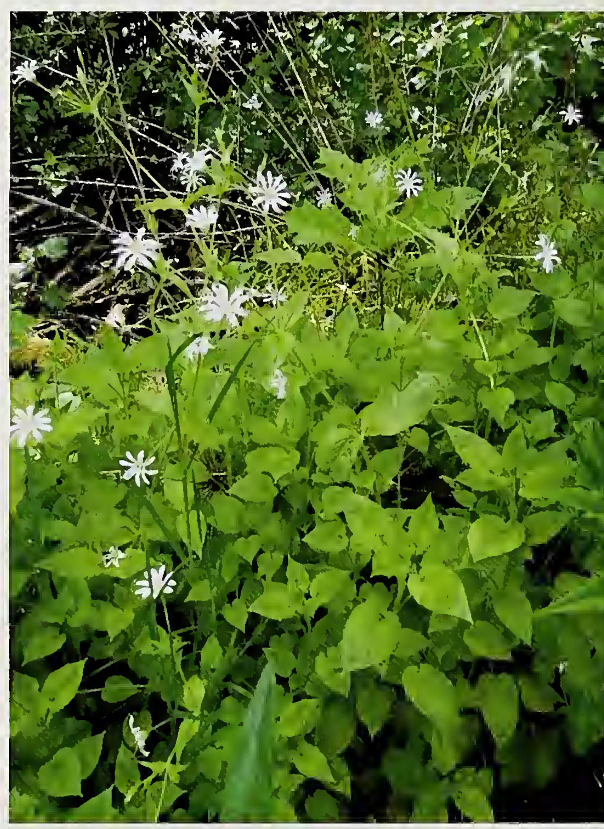

Fig.3. Wood stitchwort, *Stellaria nemorum*, native of riverbank woodland.

Fig.4. The riverbank near the University with giant hogweed and Japanese knotweed.

Fig.6. Round-leaved saxifrage, *Saxifraga rotundifolia*, rare alien, known since 1915.

Fig.5. Summer snowflake, *Leucojum aestivum* a recently spreading non-native.

Fig.7. Japanese knotweed stand below the old railway bridge, Kelvindale.

Other new residents include the now notorious Invasive Non-Native Species (INNS): Japanese knotweed, giant hogweed and Indian balsam. Giant hogweed can be an impressive sight and despite repeated efforts at poisoning, remains a highly visible presence. The balsam was known to Lee (1933) who described it as "naturalised and growing profusely on the banks of the Kelvin". This is certainly the case today, and it appears to have become even denser over the last 25 years.

Japanese knotweed (Fig.7) is perhaps the most maligned of the INNS, with a burgeoning industry thriving on its elimination. Official guidance and the popular press all report that it eliminates native species and that nothing can live under its dense canopy. Recent sampling of the spring flora at several knotweed stands along the riverbanks, some going back eight years, have shown there to be over 40 species found growing under the knotweed canopy, both native and non-native. This observation contrasts with the popular view, and agrees with the opinion of the late Oliver Gilbert (Gilbert, 2001) concerning similar riverbank populations in Sheffield. Is the Japanese knotweed a growing menace or a naturalised feature of the riverbank ecology?

Today the river is viewed as an attractive place for recreational activities and somewhere to escape, away from our busy urban lives on the streets just a few metres above the banks. To many non-botanists this appeal takes no note of the provenance of the colourful vegetation. If it is attractive now, should we leave it alone and allow nature to continue to take its course? Could we really eradicate non-natives even if we so wished? What would it be like if there were no non-natives? There are lots of difficult questions but few simple answers. Ultimately, who decides what the river and its banks should look like?

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Power from the River Kelvin: Past and Present

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Editor's note: Neil Phillips sadly died, after a short illness, while this article was in production. His activism and expertise on sustainable energy will be greatly missed.

History and Background

Since the 1500's the River Kelvin has played a part in the industry and economy of Glasgow especially Partick. Thomas the Rhymer spoke about The Miller of Partick.

At one point or another there have been mills operating on eight sites along the river within the city boundary, some of which had several names. Starting at the Bearsden / Glasgow City Boundary and travelling south down the river they were Killermont Saw Mill, Dawsholm Paper Mill (demolished in 1970's), North Woodside Mill (gunpowder, meal, dyes, flint – 1750 to 1963), South Woodside Mill (the largest cotton mill in Glasgow and the only one water p.wered), Clayslaps Mill (New Mill of Partick,1517: Waulk, Malt), Bunhouse Mill (Archbishop's Mill, Lyons Mill & later Regent Flour Mill) – 1717 ruinous but replaced by Lyons Mill in 1735 – lint, malt, snuff, flour. The building shown (Fig.1) is now flats but was the main production unit.

Below Bunhouse was the Scotstoun Mill later operated by Rank Hovis McDougall for the production of flour. This was the last operating mill, closing in 2010 but by then no longer water powered.

Further down and close to the junction with the River Clyde were the sites of the Partick Old Mill / Slit Mill, and Bishops Mill.

In order to power the mills a series of weirs and lades were constructed (Fig.2). Most of the weirs still exist but there is only one remaining lade, which is silted up. This could be cleared but restoration work would be required on the sluice gate.

Hydro Technology & Types of Turbine

There are many designs of turbine which have been installed at sites across the UK (Fig.3). The most suitable turbines for the River Kelvin will be either crossflow turbines or undershot wheels.

Turbine Principles

If you wish to generate energy and power from water you need three things – head (height), flow, and availability of flow plus an allowance for shut down maintenance (Fig.4).

As an example: For a river with a flow rate of 50 litres per second and a 15 metre head the power of a typical turbine would be:

Power = 50l/s x 15m x 9.98 x 0.75(efficiency) x 0.9(friction) /1000 = 5.05kW

The third element is availability of flow. If you assume 75% availability, how much electricity could be generated?

Electricity = 5.05 x 24 x 365 x 0.75 = 33,179kWh, which is enough electricity for about six houses.

So why has the Kelvin been used as a source of power? It is because it has water levels for flows from 2 to 200m3/sec = 2,000litres/sec to 200,000litres/sec. This means that it can be used again to generate electricity. However, it does have head limitations. From above the Killermont Weir to below the Natural Tidal Limit (NTL) Weir, the head is only 10 metres, of which 3 metres is the head across the weir.

What power could the Kelvin generate at NTL? Take a mid-range flow of 10,000litres/s; head = 3metres; turbine efficiency 0.85%; friction losses = 10%; then power = 10,000l/s x 3m x 9.98 x 0.85 x 0.9 /1000 = 229kW.

The third element is availability of flow. Let us assume 90% (it could be as high as 95%). So how much electricity could be generated?

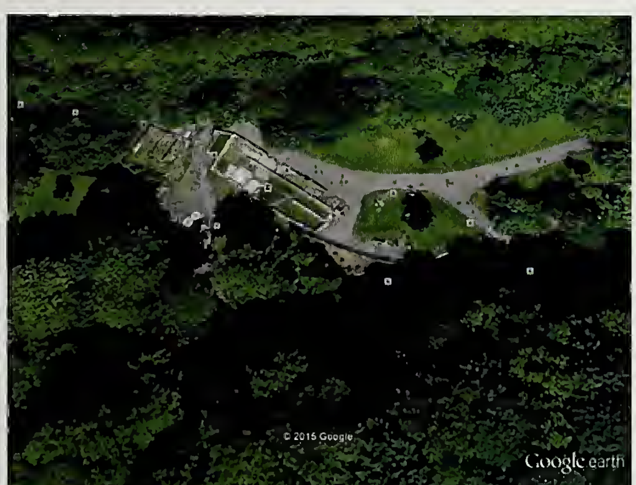
Electricity = 229 x 24 x 365 x 0.9 = 1,805,759kWh. A typical house will use about 4,500kWh per year, so the output from this weir could meet the demand of 400 houses.

Capital cost including grid connection would be about £850,000; maintenance and management would cost about £68,000 per year. If the electricity can be connected direct to properties and used, the typical cost of electricity will be 12.8p per kWh.

Fig.1. Bunhouse Mill at the present day, from the side and above.

Killermont Weir

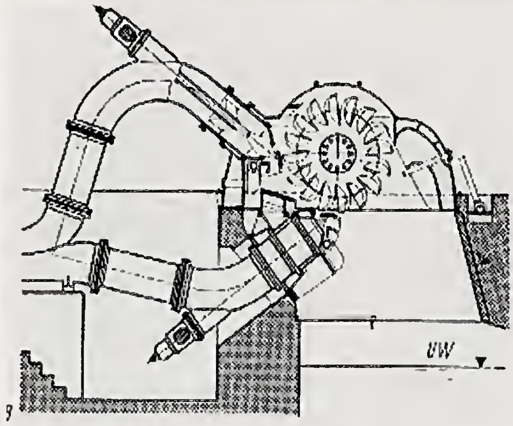
Dawsholm Weir



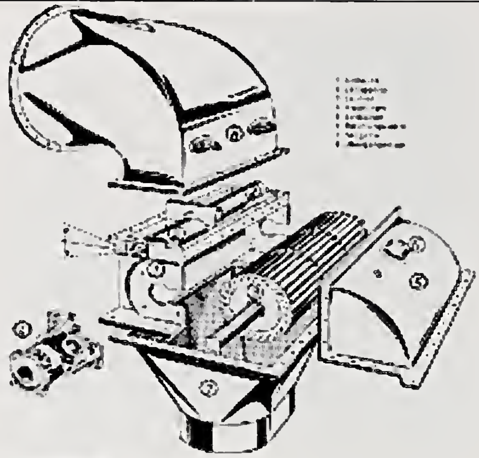
North Woodside Weir and Lade

Bunhouse Weir (Natural Tidal Weir)

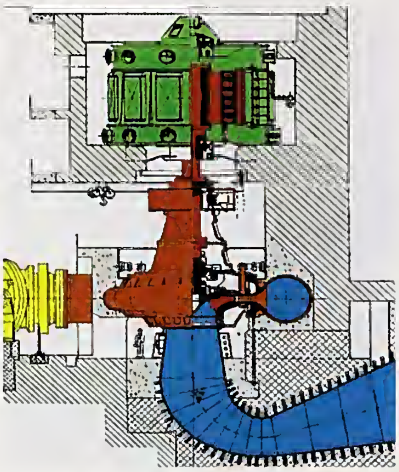
Fig.2. The weirs of the River Kelvin, from above.



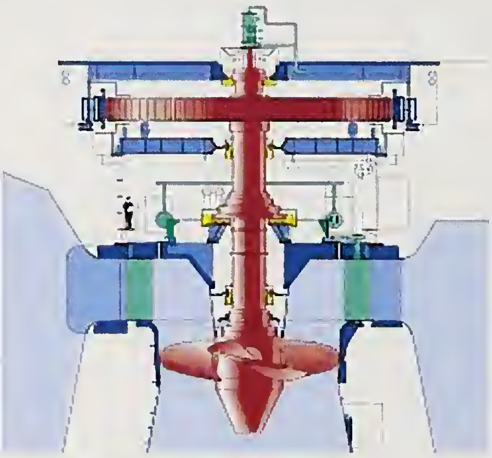
Pelton Wheel



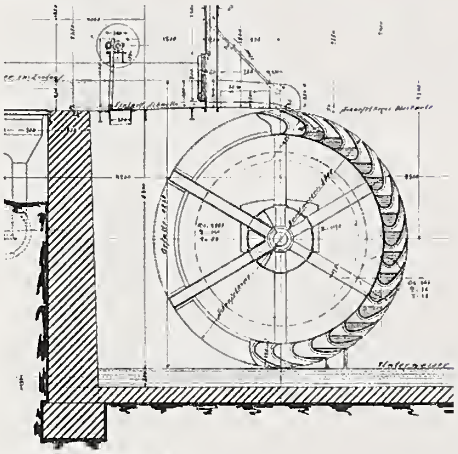
Crossflow



Francis Turbine



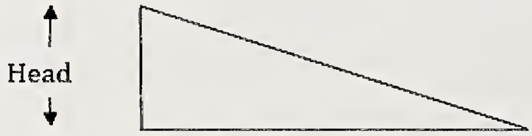
Vertical Caplan



Overshot Wheel

Undershot Wheel

Fig.3. Types of turbine for installation on rivers.



Power kW = flow in litres/s x head in metres x acceleration due to gravity x turbine efficiency x friction losses / 1000

Electricity generated = kW x 24 x 365 x availability of flow

Fig.4. Basic hydropower potential.

Generation savings = 1,805,759kWh x £0.128 = £231,137; feed-in tariff for turbines between 100kw and 500kW = 12.67p per kWh – index linked for 20 years; generation income = 1,805,759 x £0.1267 = £228,790.Savings + Income = £231,137 + £228,790 = £459,927. So simple payback = £986,000 / £459,927 = 2.14 years.

However, because there are no residential properties in the immediate vicinity, direct connection to 400 houses will not be possible so the electricity will have to be exported to the grid. Here there are no savings because of use and the export feed- in tariff is only 4.5p per kWh.

Income = 1,805,759 x £0.045 = £81,259, so simple payback = £1,666,000 / £81,259 = 20 years.
Carbon conversion for electricity = 0.53748; annual tonnes of carbon saved = 1,805,759 x 0.53748 / 1000 = 971tCO_2.

So the secret of the economic use of hydro-electricity is to use as much as possible on site. This gives us a problem with using the Kelvin because there are few high load demands close to the river. The BBC has gone, and Rank Hovis McDougall has gone. The Kelvin Hall & old Transport Museum temporarily closed for refurbishment and re-opened in 2016 as a sports and exhibition centre. The two Kelvingrove weirs combined could supply Kelvingrove Art Gallery and Museum although the head here is only 1.5m, and the electricity demand is not known.

The NTL Weir could supply the student flats on the old Western Engineering site (100), the student flats on the old Edmundson electrical site (100), the West Village student flats in Castlebank Street (700), the new student flats in Keith Street (170), and the new Vita student flat development on Castlebank Street (500).

There is potentially another site where the River Kelvin passes below the Forth and Clyde Canal aqueduct. Just west of this point are Maryhill Locks where if flow was ducted from above them through a turbine and into the bottom basin there would be a head of 9.5 metres. Unfortunately, it is not known what the availability of flow would be. It is unlikely that sufficient flow would be available for a 100kW turbine but one of say 30kW might be possible. A hydro scheme on the Kelvin at this point could be used to supplement this scheme. The output from both could supply electricity to a tower block of flats in Collina Street.

Glasgow University have commissioned a feasibility study to see if sufficient power for their development of the Western General Hospital site could be generated by a water source heat pump sited near to where the Snow Bridge crosses the river. The results of this are not yet known.

Anyone interested in learning more about small scale hydro could consult: Boyle, Godfrey (editor) (2012). *Renewable energy: power for a sustainable future* (3rd edition). Oxford University Press, Oxford and the Open University, Milton Keynes.

Discussion session

You have heard our speakers; this is your chance to discuss the issues they have raised, and any others that occur to you. We have listed a number of topics that we think will provoke some discussion, but we will be very happy if you decide to tackle some different ones. We will ask you to choose which of three groups to join for the discussion session. Each group will have three of our topics as their agenda, plus a reserve if you manage to deal with them all quickly. Each group will be led by a facilitator and will be asked to choose a scribe, whose job is to record the main points made in the discussion, and feed them back to us. The facilitator will also ask if you have any additional topics you wish to discuss.

TOPICS

Group A

1. Harnessing the Kelvin's power : are you in favour of making the investments and infrastructural changes needed to make the river a source of sustainable energy, and if so, under what conditions?
2. The banks of the Kelvin, and the river itself, have been invaded by a range of 'alien' plants and animals; should we aim to eliminate these and, if so, what resources are you in favour of spending on this task?
3. The Kelvin Biodiversity Network is a loose assembly of local groups with an interest in the river; this conference is its first substantial activity. Are you keen that the network should continue, and if so, suggest some activities for it which would not be pursued by constituent groups (such as Glasgow Natural History Society, or Friends of the River Kelvin) alone.

Group B

4. We can think of everyone living in the vicinity of the Kelvin as having a stake in the future of the river. In terms of the river's biodiversity, how can different groups of stakeholders be encouraged to take an active interest? Groups like early years children, primary and secondary school pupils, students, unemployed adults, adults with additional needs, older people, artists....
5. If you had £500 or £5000 to spend on exploring/protecting/documenting/celebrating the biodiversity of the Kelvin, how would you spend it?

6. What sources of funding should be explored to support further work on the biodiversity of the Kelvin?

Group C

7. Our uses of the Kelvin have changed greatly over the years, leaving remnants of a more industrial past, such as derelict bridges and the remains of old factories; should we now see the river as an oasis of countryside in the city, or are we prepared to support riverside developments such as more housing and hydropower generators?
8. Politicians talk a lot of 'red lines'. In terms of potential developments along the Kelvin, what would be your red lines?
9. Many users of the Kelvin are likely to be ignorant of its past but interested in learning more. If you were to be involved in developing an interpretation resource related to the river and its past, would you favour putting resources into a leaflet, fixed display boards (such as those at the Flint Mill), or new media?

Ecological monitoring of the lower River Kelvin by SEPA, 1979 – 2014

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INTRODUCTION

SEPA and its predecessor organisation have monitored the River Kelvin (Fig.1) since 1979 for the general purpose of pollution control and also for classification into one of five quality categories for the EU Water Framework Directive (WFD). The categories are High, Good, Moderate, Poor and Bad. The classification is derived using data from macroinvertebrate, diatom and macrophyte samples.

Macroinvertebrates

Ecology staff from the Clyde River Purification Board (CRPB) began regularly collecting invertebrate samples from the River Kelvin in 1979. The furthest downstream site was called Kelvin Hall and was located just upstream of the confluence with the River Clyde.

Fig 1. Sampling for invertebrates in the River Kelvin.

In 1983 that site became inaccessible due to building works, so since 1984 samples have been collected from the river in Kelvingrove Park. Over these past 35 years there have been slight changes to the methods used for sample collection and analysis, and these have been taken into account while preparing the information here.

Between 1979 and 1987 the Trent Index was the means for quantifying water quality. These scores are shown in Fig. 2. The Trent Index was replaced by BMWP (Biological Monitoring Working Party) and ASPT (Average Score Per Taxon) scores in 1989. These are shown in Fig. 3 and Fig. 4.

In 1999 stoneflies began appearing in samples, indicating an improvement in quality, perhaps associated with the diversion of effluent from Torrance Sewage Works to the Kelvin Valley Sewer (KVS). However, quality remained variable and many samples were still dominated by worms until around 2005 when samples began to indicate good quality more consistently following the diversion of other sewage effluents to the KVS. Since 2005, stoneflies and pollution-sensitive cased-caddis such as Leptoceridae and Brachycentridae (pictured Fig. 3.) have been present in nearly all samples. The Macroinvertebrate quality category improved to Moderate in 2007 and has been good since 2008. Unfortunately though, sewage effluent still floods the river intermittently when pipes and tanks become overloaded or blocked with sewage debris.

Phytobenthos (diatoms)

Typically each sample contained between 30-40 taxa. The EQR (Ecological Quality Ratio) indicates fluctuating ecological status based on diatoms. Samples with EQRs >0.6 indicate Good status and are dominated by taxa such as Achnanthidium minutissimum. Declines in EQR between 2008-09 and 2012-13 (Fig.5) could suggest the site is still nutrient enriched, with abundant taxa such as Navicula gregaria, Navicula lanceolata and Amphora pediculus recorded (Fig.5, L-R).

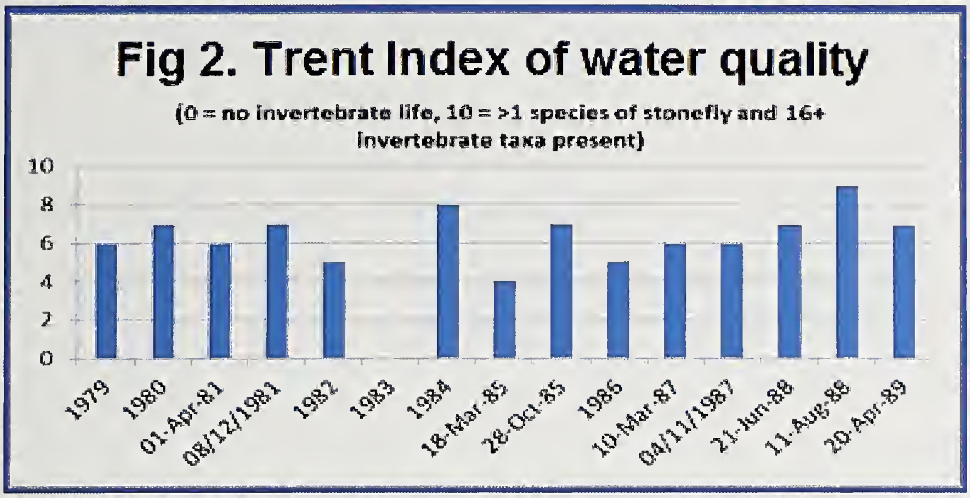
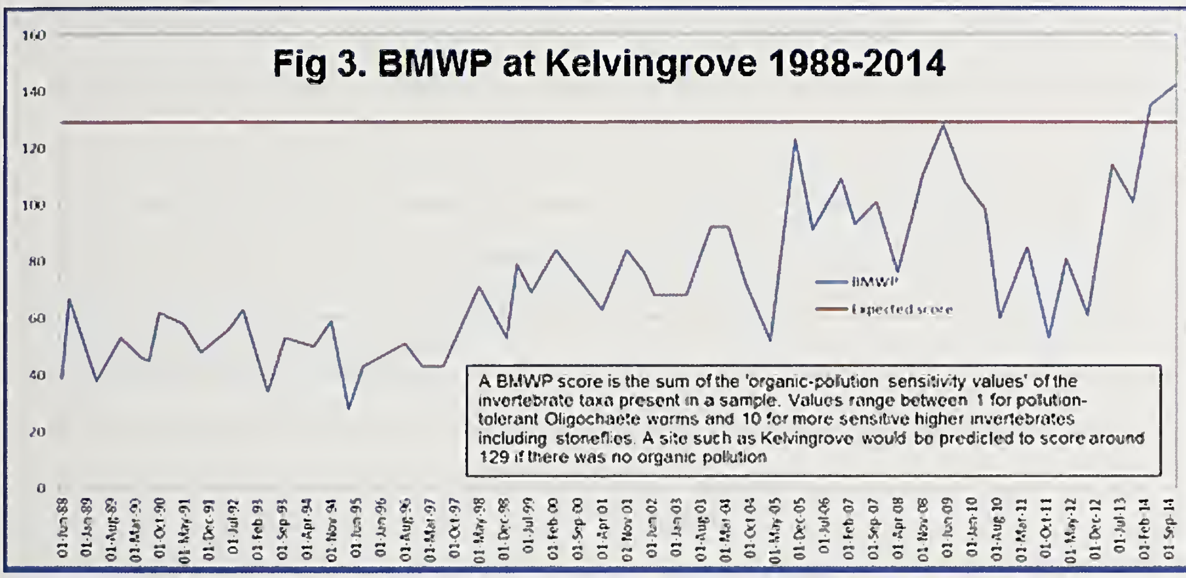


Fig 2. Trent Index of water quality.



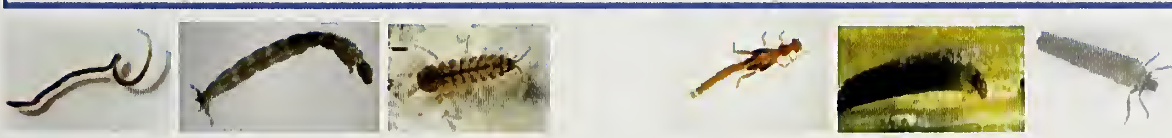


Fig 3. BMWP at Kelvingrove 1988-2014.

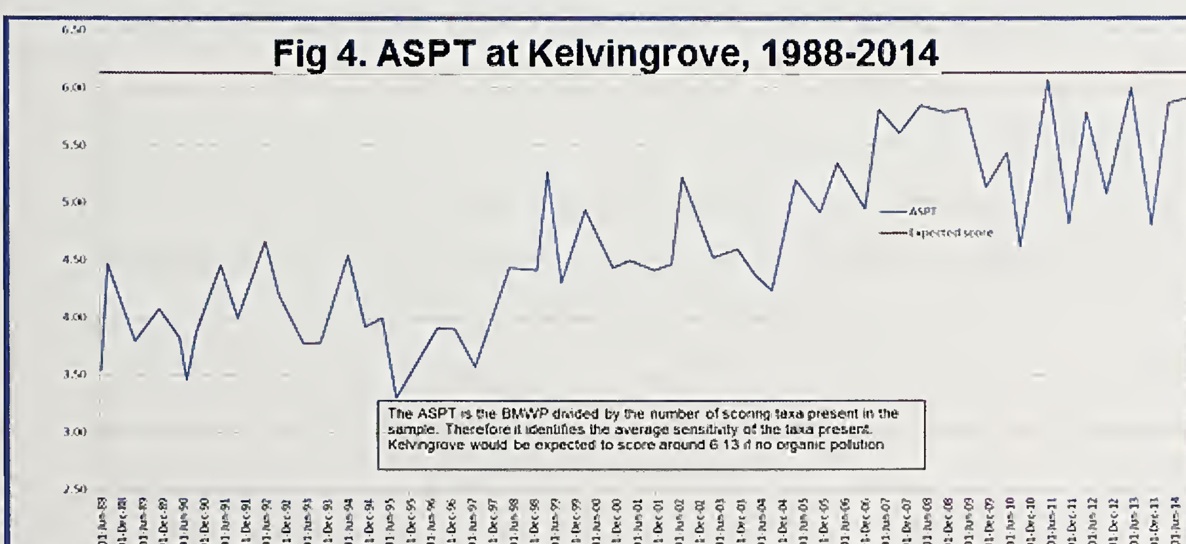


Fig 4. ASPT at Kelvingrove, 1988-2014.

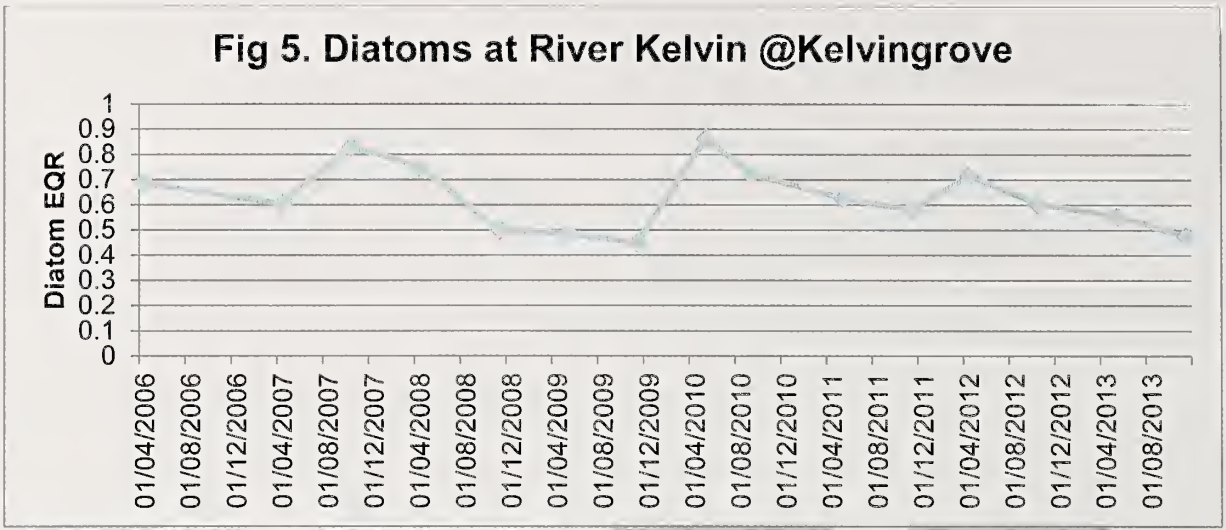


Fig 5. Diatom EQR data for the River Kelvin, 2006-2013.

Macrophytes

Macrophyte diversity and abundance were recorded at three sites along the length of the River Kelvin in 2009, with a River Macrophyte Nutrient Index (RMNI) assigned to each taxon, indicating sensitivity to nutrient enrichment. RMNI Scores range from 1 (highly sensitive) to 10 (highly tolerant). The species present indicate nutrient enriched conditions and Moderate status at Kelvingrove (Fig.6), but, overall Ecological status for WFD was Good for macrophytes, due to upstream sites on the River Kelvin scoring relatively better.

NB Kate Arnold wrote the invertebrates section; Alison McLeman the macrophytes, and Jan Krokowski the diatoms.

Dominant macrophytes species recorded during 2009 survey at Kelvingrove	RMNI
Cladophora glommerata	7.5
Phalaris arundinacea	7.52
Vaucheria sp(p)	8.41
Fontinalis antipyretica	5.4
Leptodictyon riparium	7.57
Myosotis scorpioides	6.83
Callitriche sp.	6.67
Mimulus guttatus	5.79
Sparganium erectum	8.34

Fig 6. RMNI scores rom the River Kelvin at Kelvingrove.

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FULL PAPERS

Micro moths on Great Cumbrae Island (vc100)

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ABSTRACT

Few previous records exist for micro-moths from vc100. Data are presented from the first year-round moth-trapping exercise accomplished on Great Cumbrae Island; one of the least studied of the Clyde Isles (vc100). Data from a Skinner-type light-trap, supplemented by collection of leaf mines from local trees, revealed the presence of 71 species of micro moths, representing 20 new records for the vice-county.

INTRODUCTION

The extensive nineteenth-century list of Lepidoptera in the 1901 handbook on the natural history of Glasgow and the West of Scotland issued for the Glasgow meeting of the British Association for the Advancement of Science (Elliot *et al.*, 1901) included few Cumbrae records. What records exist relate to macro moths recorded during brief visits by undergraduate classes at the Marine Station (now Field Studies Centre, Millport) or by visiting naturalists, perhaps participating in a group excursion to Cumbrae, as the Glasgow Natural History Society has done in the past. The moth fauna of Cumbrae has never received year-round attention; indeed the 'Clyde Isles' (vc100) section of Smith & Smith (1983) lacked coverage of Cumbrae. Leverton (2001, Appendix 1) was able to estimate only the macro moth species diversity of the Clyde Isles (at 275 species) and it was not until 2008 that the first moth list for the adjacent islands of Bute and Inchmarnock was published by Collis & Collis (2008), including some micro moth records. Micro moths in vc100 have certainly been under-recorded locally, a not unusual circumstance (Kinnear & Kirkland, 2000; Knowler, 2016).

SITES AND METHODS

A Skinner-type light trap ('Portable Suitcase Moth Trap (MT01): Wildforms, Stranraer) using two 20W fluorescent bulbs issuing 100W+ per bulb was deployed under the canopy of my garden office verandah at "Redcliff" (NS171547), looking west over a sheltered lawn in a coastal situation (elevation *ca.* 8m). The light source was situated *ca.* 125cm above ground level. The following mature flower clumps and shrubs were present within a 7m radius: red-hot poker (*Kniphofia uvaria*), honeysuckle (*Lonicera* sp.), *Magnolia* sp. and *Forsythia* sp. Behind the office is a large mature black mulberry tree (*Morus nigra*) and to one side is a tall privet hedge (*Ligustrum ovalifolium*). To the rear of my property is a wooded escarpment with old-growth ash (*Fraxinus excelsior*) frequently ivy-covered (*Hedera helix*), sycamore (*Acer pseudoplatanus*) and rowan (*Sorbus aucuparia*), with an undergrowth of hawthorn (*Crataegus monogyna*), wild garlic (*Allium ursinum*), nettle (*Urtica dioica*), bracken (*Pteridium aquilinum*) and bramble (*Rubus fructicosus*). Rhind (1988) detailed the vascular plants found on Great Cumbrae Island between 1985 and 1987 and delineated the history of the island's botanical investigations. Leaves of brambles in my garden, beech trees (*Fagus sylvatica*) and hazel (*Corylus avellana*) at other locations on the island (respectively Craiglea Wood (NS175566; referenced herein as CW), the eastern margin of the island's perimeter road (NS182553; referenced as EM) and the roadside, Farland Point (NS175544; referenced as FP)), were sampled for leaf-mining stigmellids.

After some preliminary deployments in September and October 2015 (which yielded no micro moths), the light trap was employed extensively from 24 March 2016 to 23 March 2017 on as many occasions as proved feasible and personal circumstances allowed, which amounted to 148 nights sampled. Nights when heavy rain or gales were forecast were avoided, given the vulnerability of the light trap. A few later records are included. Micro moth determinations have been greatly facilitated by Sterling & Parsons' field guide (2012). Most helpful for checking distribution are the maps compiled by the East Scotland Branch of Butterfly Conservation (www.eastscotland-butterflies.org.uk/scottishmicros.html; accessed 19 October 2016 *et seq.*). Other relevant websites proved useful for checking identities and distribution data (notably ukmoths.org.uk, www.ukleps.org and lepiforum.de).

Micro moths of uncertain identity were either retained frozen as voucher specimens or photographed (or both). Confirmation of micro moth

identifications was obtained from Nigel G. J. Richards (a member of the Scottish Micro Moth Verification Panel) either photographically via the Scottish Moths Group e-mail facility, directly by e-mailing photographs to an expert or by submission of voucher material and genitalia dissection. Mark Young kindly confirmed the identity of certain stigmellid leaf miners. I am grateful to all, but especially to Nigel Richards, for patience and forbearance of this tyro lepidopterist's efforts, both at photography and identification, and latterly for his helpful comments on the first draft of this paper. I should like also to acknowledge the helpful assistance received from Glyn Collis (county moth recorder for vc100). Inspiration has been derived from the publications of Leverton (2001) and Plant (2008).

Night-time minimum temperatures and weather conditions were recorded after each trap deployment, beginning 13 April 2016. Data on the erebid macro moth, Pinion-streaked Snout (*Schrankia costaestrigalis*), are also included here since it is often mistaken for a micro (Sterling & Parsons, 2012: 28).

RESULTS

Data on occurrences and seasonality of 71 micro moth (together with data on one macro) species are presented in Appendix 1. For the most part micros occurred as singletons in my trap, the few exceptions (on occasions) being the Diamond-back Moth (*Plutella xylostella*), *Blastobasis adustella*, *B. lacticolella*, the Twenty-Plume Moth (*Alucita hexadactyla*), the Barred Fruit-tree Tortrix (*Pandemis cerasana*), *Clepsis consimilana, Epiblema scutulana*, Small Magpie (*Anania hortulata*), *Eudonia angustea, E. mercurella, Chrysoteuchia culmella, Agriphila tristella* and *A. straminella.*

The proportion of micro to macro moths in the light trap varied seasonally with maximum occurrences of micros in the summer months (May to September, with a few in early October). Mean overnight minimum temperatures are given in Table 1.

Date	Min temperatures
13-30/04/2016	4.5
01-31/05/2016	9.6
01-30/06/2016	13.3
05-31/07/2016	14
01-31/08/2016	13.4
01-30/09/2016	13.5
01-31/10/2016	9.2
01-30/11/2016	4.9
01-31/12/2016	7.6
01-31/01/2017	4.7
01-28/02/2017	4.8
01-23/03/2017	5.8

Table 1. Mean monthly overnight minimum temperatures (ºC) at monitoring site.

DISCUSSION

It is not unusual to find that micro moths are under-recorded in any area (Knowler, 2016), so the paucity of data on Great Cumbrae Island is not unexpected. Collis & Collis (2008) recorded 31 micro moth species in their contribution on moths from Bute and it is interesting to compare their list with mine. Of the species recorded by Collis & Collis, only 19 are shared in my list. Doubtless this will relate to habitat differences in the vicinity of the trap sites between these adjacent islands. The very large catches of *Scoparia ambigualis* reported from Mugdock Country Park (Stirlingshire) by Knowler (2016) are unmatched in my data, and none of the highly distinctive *Yponomeuta evonymella* (Bird-Cherry Ermine), similarly prominent in Knowler's data, was recorded by me, although Collis & Collis (2008) did record it from Bute (suggestive of an absence here of its host tree, *Prunus padus*).

My investigation has established 20 new records for micro moths in vc100: *viz. Stigmella microtheriella, S. floslactella, S. tityrella, S. hemargyrella, Caloptilia rufipennella, Borkhausenia fuscescens, Diurnea fagella, Agonopterix nervosa, A. yeatiana, Blastobasis adustella, Pterophorus pentadactyla, Emmelina monodactyla, Clepsis consimilana, Epiphyas postvittana, Eana penziana, Apotomis betuletana, Notocelia cynosbatella, Cydia splendana, Scoparia subfusca* and *Catoptria pinella.*

All these are common species and widespread in Britain, so the previous absence of records locally reflects an absence of recorders. It remains important, though, that as much information as possible be forthcoming from neglected sites, even for common species. *Caloptilia rufipennella* is interesting in that it was discovered in Britain only in 1970 and has been gradually expanding its range ever since. *Epiphyas postvittana*, by contrast, came over here from Australia in the 1930s (www.ukmoths.org.uk; accessed 18 October 2016). Problematic infestation of brassicas by the migratory *Plutella xylostella* was reported in June 2016 from several monitoring sites in S. England; a two-mile-long cloud of these moths being reported near Leominster, Herefordshire, the high numbers so reported being unmatched for the past 20 years, with reports even reaching the national press (Knapton, 2016). Only two specimens were recorded by Knowler (2016) in 2006 from Mugdock Country Park (Stirlingshire). Numbers can fluctuate markedly from year to year. The leaf-mining moth *Cameraria ohridella*, first recorded in Britain in 2002 and now rapidly spreading north and west (Sterling & Parsons, 2012), currently threatens horse-chestnut trees (*Aesculus hippocastanum*) in England. There has been one confirmed sighting in Scotland (Forestry Commission website, as updated 27 September 2016; see www.forestry.gov.uk/horsechestnutleafminer , accessed 24 October 2016). It is another micro moth

that has made the national newspapers (Eleftheriou-Smith, 2016; Fox-Leonard, 2016). But, having examined the leaves of local horse-chestnut trees, I can affirm it has not reached Cumbrae (yet). The potential role of herbaria and archival DNA in tracking the origins of this invasive herbivore has been highlighted by Lees *et al.* (2011).

Note added in press:
A Small Magpie moth trapped 26 May 2017, has been confirmed as correctly identified by Nigel Richards, substantiating my earlier record (see above).

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Appendix 1. Micro moths of Great Cumbrae Island: abundance and seasonal occurrence

As per convention (Leverton, 2001), dates here recorded relate to dates of overnight trap deployment not dates of dismantling (which my notebooks record). Dates predominately reflect 2016 results. Any 2017 data are in parentheses. A single asterisk for *Gracillaria syringella* records that leaf mines were present on my privet hedge in addition to adults trapped. Any of my records not available for Nigel Richards' scrutiny of voucher material are marked with a double asterisk. Marked with a treble asterisk is the White-Plume moth (*Pterophorus pentadactyla*), which was found on the lawn in front of my garden office during the day, near to a bindweed plant (*Calystegia sepium*). †Signifies confirmed by Roy Leverton from photograph; §found inside and outside house; !!found outside house. Species numbering follows the latest check-list of Agassiz *et al.* (2013). In parentheses is the species number relating to Bradley's earlier check-list (2000).

	Numbers	Earliest date	Latest date
Family **Nepticulidae**			
4.010 (111) *Stigmella microtheriella* (EM, leaf mines in hazel)			
4.024 (104) *Stigmella magdalenae* (CW, leaf mines in rowan)			
4.032 (75) *Stigmella floslactella* (EM, leaf mines in hazel)			
4.034 (77) *Stigmella tityrella* (CW, leaf mines in beech)			
4.035 (68) *Stigmella salicis* (FP, leaf mines in sallow)			
4.045 (50) *Stigmella aurella* (leaf mines in bramble)			
4.055 (81) *Stigmella hemargyrella* (CW, leaf mines in beech)			
Family **Gracillariidae**			
15.004 (282) *Caloptilia elongella*	1	24/09	
15.006 (284) *Caloptilia rufipennella*	1	13/09	
15.014 (293) *Gracillaria syringella**	1	09/08	
Family **Ypsolophidae**			
17.011 (461) *Ypsolopha ustella*	1	30/10	
Family **Plutellidae**			
18.001 (464) *Plutella xylostella*	16	09/06	18/07
Family **Glyphipterigidae**			
19.002 (397) *Glyphipterix thrasonella*	1	06/06	
Family **Oecophoridae**			
28.009 (648) *Endrosis sarcitrella*	1	14/08	
28.010 (647) *Hofmannophila pseudospretella*	3	22/06	11/07
28.012 (644) *Borkhausenia fuscescens*	1	21/07	
Family **Chimabachidae**			
29.001 (663) *Diurnea fagella*!!	1	(06/04)	
Family **Depressariidae**			
32.007 (701) *Agonopterix ocellana ***	1	05/ 05	
32.017 (697) *Agonopterix arenella*	3	14/08 (06/04)	29/08
32.029 (705) *Agonopterix umbellana*	1	18/09	
32.030 (706) *Agonopterix nervosa*	2	21/07	20/08
32.035 (714) *Agonopterix yeatiana*	1	(08/04)	
32.039 (670) *Depressaria daucella*§	(3)	(17/01)	(06/04)
Family **Gelechiidae**			
35.038 (789) *Bryotropha domestica*	1	04/08	
35.040 (787) *Bryotropha terrella*	1	23/07	
Family **Elachistidae**			
38.026 (598) *Elachista kilmunella*	1	04/06	

Family **Blastobasidae**			
41.002 (873) *Blastobasis adustella*	17	18/07	30/10
41.003 (874) *Blastobasis lacticolella*	38	30/05	29/10
Family **Alucitidae**			
44.001 (1288) *Alucita hexadactyla***	10	05/05	13/09
Family **Pterophoridae**			
45.010 (1497) *Amblyptilia acanthadactyla*	1	23/07	
45.030 (1513) *Pterophorus pentadactyla****	1	11/07	
45.044 (1524) *Emmelina monodactyla*	3	05/09 (08/04) (10/04)	
Family **Tortricidae**			
49.025 (970) *Pandemis cerasana*	9	16/06	14/08
49.029 (1002) *Lozotaenia forsterana*	2	15/07	26/07
49.031 (989) *Aphelia paleana*	1	31/07	
49.038 (994) *Clepsis consimilana*	5	05/06	16/08
49.039 (998) *Epiphyas postvittana*	3	13/09	05/10
49.048 (1013) *Eana penziana*	1	26/07	
49.066 (1038) *Acleris laterana*	2	23/08	27/09
49.069 (1041) *Acleris sparsana*	1	13/09	
49.077 (1048) *Acleris variegana*	4	15/09	05/10
49.091 (1011) *Pseudargyrotoza conwagana*	1	15/07	
49.111 (954) *Eupoecilia angustana*	1	05/06	
49.127 (945) *Aethes cnicana*	1	18/07	
49.150 (1093) *Apotomis betuletana*	2	09/06	16/06
49.156 (1083) *Hedya nubiferana*	2	15/06	20/06
49.166 (1076) *Celypha lacunana*	2	09/06	18/07
49.194 (1111) *Bactra lancealana*	1	20/06	
49.195 (1110) *Bactra furfurana*	1	06/06	
49.214 (1126) *Ancylis badiana*	6	12/05	29/08
49.248 (1139) *Epinotia tenerana*	1	14/08	
49.285 (1184) *Epiblema scutulana*	2	12/06	
49.292 (1174) *Notocelia cynosbatella*	7	05/06	08/07
49.294 (1175) *Notocelia uddmanniana*	2	18/07	23/07
49.298 (1176) *Notocelia trimaculana*	1	17/06	
49.341 (1260) *Cydia splendana*	1	23/07	
Family **Pyralidae**			
62.001 (1428) *Aphomia sociella*	3	06/06	18/07
Family **Crambidae**			
63.025 (1376) *Anania hortulata* (Small Magpie)**	7	06/06	23/06
63.038 (1405) *Pleuroptya ruralis* (Mother of Pearl)** †	1	23/07	
63.057 (1356) *Evergestis forficalis* (Garden Pebble)	2	23/07	31/07
63.062 (1332) *Scoparia subfusca*	5	16/06	06/08
63.064 (1334) *Scoparia ambigualis*	7	05/06	06/08
63.069 (1342) *Eudonia angustea*	4	29/08	01/10
63.074 (1344) *Eudonia mercurella*	14	11/07	23/08
63.080 (1293) *Chrysoteuchia culmella*	39	04/06	23/08
63.081 (1294) *Crambus pascuella*	1	29/07	
63.088 (1302) *Crambus perlella*	1	23/07	
63.089 (1305) *Agriphila tristella*	44	03/06	29/08
63.093 (1304) *Agriphila straminella*	21	14/06	12/08
63.099 (1313) *Catoptria pinella*	1	11/07	
63.100 (1314) *Catoptria margaritella*	1	23/07	
Family **Erebidae** (Macro moth)			
72.061 (2484) *Schrankia costaestrigalis* (Pinion-streaked Snout)	2	29/07	31/07

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The latest chapter in a conservation story: completing 10 years of post-translocation monitoring for a population of great crested newt (*Triturus cristatus*) in Scotland

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ABSTRACT

During the late 1990s, industrial development threatened a large population of great crested newt (*Triturus cristatus*) at Gartcosh, North Lanarkshire, Scotland. In 2004 - 2006, the population was relocated during the first *ex situ* conservation-based translocation in Scotland, from Gartcosh Industrial Site to the specially created Gartcosh Nature Reserve (GNR). By 2006, 1,012 great crested newts had been translocated to GNR. Peak adult counts obtained by torchlight survey in 2006 were low but continued to increase steadily, exceeding 400 adults in 2010. Later monitoring recorded a decline with 221 adults in 2011. Thereafter, surveys consistently recorded over 400 adults but no monitoring occurred in 2014. In 2015, the highest counts (515 adults) throughout the entire monitoring period were recorded, and a significant increase in overall population growth over time (1998 - 2003, 2006 - 2013, 2015) identified. Until 2011, amphibian fencing prevented great crested newt migration between each of the four zones within GNR and each zone effectively contained a great crested newt subpopulation. When adult counts within zones over time (2006 - 2013, 2015) were examined, two zones had increased whilst two zones had declined. Significant differences in mean counts were found for all zones, with overall growth highest in Bothlin Burn. This may indicate migration between zones, or differences in habitat allowing two zones to thrive whilst the other two faltered. The population retains its status as the largest in Scotland, with the effect of the translocation being negligible or positive. However, our results indicate the need for continued monitoring of translocated amphibian populations and studies on great crested newt migration. Additionally, the zone declines indicate that some ponds may be less favourable and require modification to remain suitable for great crested newts in the longer term.

INTRODUCTION

In 2004, the International Union for Conservation of Nature (IUCN) Amphibian Specialist Group published a Global Amphibian Assessment (GAA) which estimated that 32.5% of amphibian species are threatened with extinction, in comparison with 23% of mammals and 12% of birds (Stuart *et al.*, 2004). Although the amphibian database has been updated twice since the GAA in 2004 (IUCN, 2008), the GAA was the last comprehensive amphibian assessment made and the outcomes remain pertinent in amphibian conservation today. Human exploitation of aquatic and terrestrial ecosystems (Denöel & Ficetola, 2008) continues to expose amphibians to "a cocktail of abiotic and biotic stressors" (Blaustein & Kiesecker, 2002). As a result, 42% of amphibian species are in decline (IUCN, 2008). Diagnosis for decline is complex as decline factors have close interactions and the effects of any one factor are often context dependent (Beebee & Griffiths, 2005). Additionally, threats to many species are likely to be underestimated due to data deficiency (Howard & Bickford, 2014). Therefore, recommendations to halt declines can only be made and implemented from consistent long-term monitoring programmes (Kröpfli *et al.*, 2010).

The great crested newt (*Triturus cristatus*), hereafter GCN, is widely distributed across mainland Europe and the UK, although UK populations tend to be localised in their occurrence (Edgar & Bird, 2006; Beebee, 2015; O'Brien *et al.*, 2015). GCN have declined across their range in the UK due to housing and industrial development, and agricultural intensification. Ponds have also been stocked with fish for recreational angling without consideration of potential predation on newt larvae (Langton *et al.*, 2001). Consequently, suitable GCN habitat has been lost or become degraded (Gent, 2001; Edgar *et al.*, 2005; Edgar & Bird, 2006; O'Brien, 2016). GCN are ill-equipped to cope with loss of breeding ponds due to their breeding and dispersal strategies; adults are philopatric to breeding ponds and migration to new ponds is limited to distances around 1.6km (Edgar & Bird, 2006; Beebee, 2015; Haubrock & Altrichter, 2016). Breeding success is further impaired by 50% egg abortion caused by a chromosomal defect

(Macgregor, 1995). The habitat requirements of GCN are specific, unlike other widespread amphibians and GCN infrequently occupy urban or garden ponds (Oldham *et al.*, 2000; Gustafson *et al.*, 2009; Beebee, 2015). The combination of these factors has reduced, fragmented and isolated populations (O'Brien *et al.*, 2015).

GCN are a species of international importance, listed on Annexes II and IV of the EC Habitats Directive, Appendix II of the Bern Convention, and the IUCN Red List of Threatened Species with a decreasing population trend, although classed 'Least Concern' due to widespread distribution (IUCN, 2016). GCN populations are protected by UK and European legislation at all life stages (Rees *et al.*, 2014b; Gustafson *et al.*, 2016; Lewis *et al.*, 2016). In the UK, GCN are protected by Schedule 2 of the Conservation *(Natural Habitats etc.)* Regulations, 1994. European legislation is enforced under the Conservation of Habitats and Species Regulations, 2010. This legislation states it is an offence to kill, injure or take GCN individuals. Disturbance is prohibited and breeding sites and hibernacula are protected (McNeill *et al.*, 2012). Where land development threatens GCN, developers are required to survey for them. If surveys reveal GCN in the UK, developers must propose mitigation for GCN and their habitat (Edgar *et al.*, 2005; Lewis *et al.*, 2013; Lewis *et al.*, 2016) in order to obtain a licence from the relevant government regulatory agency (e.g. Natural England, Scottish Natural Heritage) before proceeding with development (McNeill *et al.*, 2012).

In England, the 'rare' status of GCN is frequently disputed due to widespread distribution of populations, many of which conflict with development (Lewis *et al.*, 2016). Indeed, the cost of conservation measures has received negative coverage in journalistic media, with suggestions that GCN do not require such measures and that they involve misuse of government funding. Conversely, in Scotland, the species is uncommon with a restricted distribution in the south and highlands of Scotland. The majority of populations are small despite being present in around 200 locations in Scotland (O'Brien *et al.*, 2015; O'Brien, 2016). The largest population of GCN in Scotland can be found at Gartcosh, North Larnarkshire. With 1,012 adults counted by trapping in 2006, this local population was estimated to represent 9-29% of the overall Scottish population (McNeill, 2010).

During the 1990s, industrial development threatened this significant population of GCN. From 2004 – 2006, the population was relocated in the first conservation-based translocation in Scotland, from the Amphibian Conservation Area (ACA) within Gartcosh Industrial Site to the specially created Gartcosh Nature Reserve (GNR) (McNeill, 2010; McNeill *et al.*, 2012). Maps of GNR (Fig. 1; Appendix 1) in relation to ACA (Fig. 2) are provided. The licence granted by the Scottish Executive required 10 years of post-translocation monitoring, but this was supplemented by an intensive research project funded by Scottish Natural Heritage and carried out by DCM in consultation with North Lanarkshire Council (NLC) from 2006 – 2010 (NcNeill, 2010). Thereafter, torchlight surveys were conducted by environmental consultancies but concluded in 2013. In 2015, the most recent year of post-translocation monitoring was completed by LRH as part of a University of Glasgow Masters research project.

Amphibian monitoring in the UK commonly uses torchlight survey, which requires less training and time than other methods such as bottle-trapping and netting (Gent & Gibson, 1998; Langton *et al.*, 2001; Sewell *et al.*, 2013). It is thought to cause little disturbance and is applicable to large-scale, volunteer recording schemes (Langton *et al.*, 2001; Kröpfli *et al.*, 2010). Torchlight surveys are conducted in the breeding season, between March and June. A surveyor walks slowly around the edge of a pond with a high-powered torch scanning the marginal vegetation and pond bottom. Since newt activity varies with temperature, surveys are recommended when air temperature exceeds 5°C (Langton *et al.*, 2001; Sewell *et al.*, 2013). In comparison to many tropical amphibians, temperate amphibians (such as those in the UK) are seasonal and have relatively short breeding seasons, reducing the survey timeframe. Bad weather can prolong breeding but impedes survey effort (Griffiths & Inns, 1998; Sewell *et al.*, 2013). Hence, surveys are best conducted on warm, calm nights without rain and wind, which cause water perturbation. Torchlight survey is a monitoring requirement for population assessment of GCN pre- and post-translocation (Natural England, 2015).

Translocation has been reviewed as a mitigation method for GCN (Oldham *et al.*, 1991; Oldham & Humphries, 2000; May, 1996; Edgar & Griffiths, 2004; Edgar *et al.*, 2005; Lewis *et al.*, 2007; Lewis, 2012; Gustafson *et al.*, 2016; Lewis *et al.*, 2016) but the effectiveness of translocation remains largely unknown due to lack of pre- and post-translocation monitoring in addition to sparse publication of reports on translocation success or failure (Gustafson *et al.*, 2016; Lewis *et al.*, 2016). Consequently, approximated annual investment of £20 - £40 million into mitigation by translocation in the UK (Lewis *et al.*, 2016) may be open to question. Furthermore, data deficiency of GCN distribution records cannot be mitigated by volunteer recording due to the protected species status of GCN, which requires surveyors to either possess a species licence or be accompanied by a licence holder (McNeill *et al.*, 2012).

Fig. 1. Google Map of GNR showing all four zones: Bothlin Burn, Stepping Stone, Garnqueen Hill and Railway Junction. Bothlin Burn consists of eight ponds in two clusters (BB1-BB8), whereas Stepping Stone is a small cluster of three ponds (SS1-SS3). Garnqueen Hill consists of seven ponds in two clusters (GQ1-GQ7) and Railway Junction consists of six ponds (RJ1-RJ6). Peak adult counts obtained for GCN in each pond are indicated by size of points (grey).

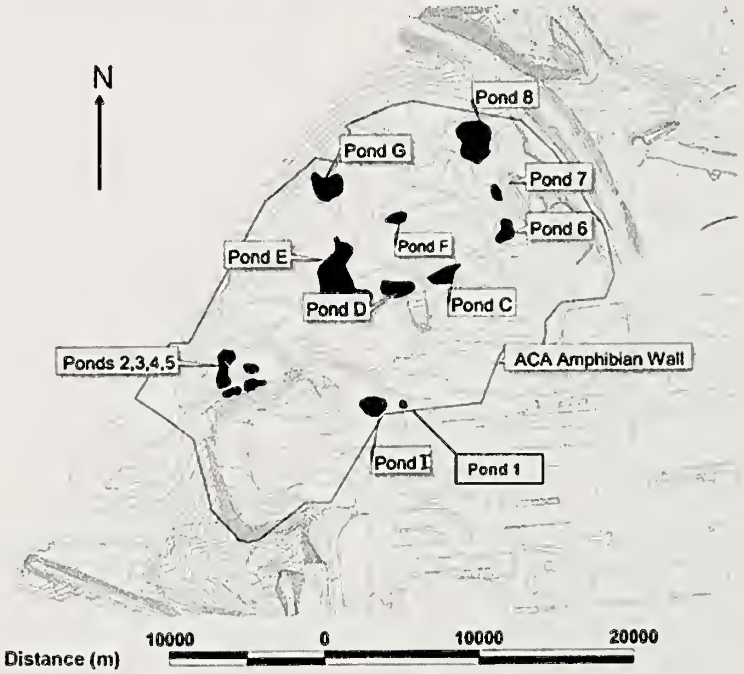

Fig. 2. Map of ponds located within the Amphibian Conservation Area (ACA), which was the donor site for the GCN translocation. Six (C,D,E,F,G,I) of the seven original ponds are shown on the map; pond L is not. Ponds 1-8 were created when the ACA was established and amphibian wall built. Map reproduced with permission from Ironside Farrer. Modified by McNeill (2010) to show the location of Pond 1.

Here, we report on the results of a translocation for GCN in Scotland. With six years of pre-translocation data and 10 years of post-translocation data, we now have a long-term study from which to infer conclusions. Our overarching aim was to assess the impact of translocation to guide future conservation of this GCN population. Our specific objectives consisted of population analysis over time, at the level of the entire site and at specific zones within the site. To address these objectives, we assessed: population size within GNR over the entire monitoring period (1998 – 2003, 2006 – 2013, 2015); adult counts within GNR over the post-translocation monitoring period (2006 – 2013, 2015); and whether adult counts in each zone of GNR over the post-translocation monitoring period (2006 – 2013, 2015) were substantially different to one another. The GCN population at Gartcosh appears to have increased post-translocation and retains its status as the largest in Scotland. Translocation may therefore be an effective conservation mitigation strategy. However, our results also indicate the need for continued monitoring, encompassing all life stages of translocated amphibian populations, and studies on GCN migration. Additionally, the zone declines we detected indicate that some ponds may be less favourable and may require modification to support more GCN.

MATERIALS AND METHODS

Study site & data collection

GNR contains 24 ponds distributed across four distinct zones: Bothlin Burn (BB), Stepping Stone (SS), Garnqueen Hill (GQ) and Railway Junction (RJ) (Fig. 1; Appendix 1). Each pond was surveyed by torchlight 4 – 6 times during March – June each year from 2006 – 2015, except 2014. Surveys started 30 minutes after dusk on calm, dry nights with temperatures exceeding 5 °C. The order of ponds surveyed during each visit was randomised. Observers walked slowly around each pond with a Cluson 1,000,000 candlepower torch, checking for all adult amphibians in the torch beam at 1 m intervals, and recording observations (species, number, and sex). Total adult counts were recorded after one full circuit, in accordance with standard methodology (Gent & Gibson, 1998). Amphibian species other than GCN are not reported in this paper. Where possible, 100% of the shoreline was searched. Survey time per pond was dependent on pond size. A complete survey of all 24 ponds took approximately 10 hours over three consecutive nights. Surveys were standardised by using the same type of torch, bulb and battery strength. The maximum counts per pond were summed to produce zone and site counts, following which population sizes were classed in accordance with guidelines established by English Nature (2001). The survey protocol is shown in Appendix 2: the habitat data recorded are not reported in this paper, nor are the numbers of amphibians other than GCN.

Data analysis

All data analysis was performed using the statistical programming environment R v 3.3.2 (R Core Team, 2016). A Generalised Linear Model (GLM) was fitted to adult count data from the entire monitoring period (1998 – 2003, 2006 – 2013, 2015) to test for the relationship between 'adult counts' (response variable) and the explanatory variable 'year'. A second GLM was fitted to adult count data from subpopulations in each zone of GNR from the post-translocation monitoring period (2006 – 2013, 2015). This GLM was used to assess change in adult counts over time and variation in adult counts between zones of GNR that were established post-translocation. The GLM tested for correlation between 'adult counts' (response variable) and two explanatory variables, 'year' and 'zone'.

A negative binomial distribution was specified for all models as the response variable was integer count data and Poisson distributed models initially specified were overdispersed when tested ($P < 0.05$) using the R package RVAideMemoire v 0.9-45-2 (Hervé, 2015). A negative binomial distribution can control for aggregation in count data and prevent biased parameter estimates (Harrison, 2014). All models considered were nested and so the best model was chosen using stepwise backward deletion of terms based on Likelihood Ratio Tests (LRT). Final negative binomial models were tested for overdispersion as above and model fit assessed using the Hosmer and Lemeshow Goodness of Fit Test (Hosmer & Lemeshow, 2000) within the R package 'ResourceSelection' v 0.2-4 (Lele *et al.*, 2014) and by visual examination of fit and residuals. Model predictions were obtained using inbuilt R functions (R Core Team, 2016) and model results plotted for evaluation using the R package 'ggplot2' v 2.1.0 (Wickham, 2009). A Tukey's Posthoc Test was performed on the second GLM to generate pairwise comparison of means for all levels of the factor 'zone' using the R package 'multcomp' v 0.1-7 (Hothorn *et al.*, 2009).

RESULTS

Torchlight survey

Prior to translocation, the GCN counts at Gartcosh were consistently low (under 100 breeding adults), excluding a pre-translocation peak of 140 adult GCN in 2001 (Table 1, Fig. 3). Counts initially remained low post-translocation in 2006 and 2007 but increased to 299 adults in 2008. Counts then dipped slightly in 2009 before doubling in 2010 to 432 adults. Thereafter, there was a sharp decline as adult counts halved in 2011 but numbers recovered by 2012 with 454 adults recorded, remaining high with 428 GCN counted in the last year of monitoring by environmental consultants (2013). In 2015, the highest adult counts throughout the entire monitoring period were observed, with 382 males and 133 females (Appendix 3) totalling 515 adult GCN (Table 1). Despite GCN adults being released

into GNR with a sex ratio of 1:1 ±10%, with males being slightly higher (Table 1), torchlight surveys repeatedly displayed a substantial male bias, ranging from 1: 2.3 to 1: 4.2 over the course of the 10-year post-translocation monitoring period (Table 1).

Pre-translocation		Post-translocation						
Year	**ACA**	**Year**	**Adults**	**GNR**	**BB**	**SS**	**GQ**	**RJ**
1998	68	**Trans**	M	529	285	-	217	217
		Pop 04-06	F	483	246	-	208	208
			Total	**1012**	**531**	-	**425**	**425**
1999	66	**HEL 2006**	M	67	36	1	20	10
			F	29	17	0	5	7
			Total	**96**	**53**	**1**	**25**	**17**
2000	93	**HEL 2007**	M	76	43	2	16	13
			F	32	11	1	12	8
			Total	**108**	**54**	**3**	**28**	**21**
2001	140	**HEL 2008**	M	241	142	0	31	68
			F	58	35	0	10	13
			Total	**299**	**177**	**0**	**41**	**81**
2002	77	**HEL 2009**	M	195	118	1	64	12
			F	54	37	0	13	4
			Total	**249**	**170**	**1**	**77**	**16**
2003	78	**URS 2010**	M	320	197	6	60	63
			F	112	74	3	25	17
			Total	**432**	**271**	**9**	**85**	**80**
		URS 2011	M	166	93	1	65	36
			F	55	24	0	26	7
			Total	**221**	**117**	**1**	**91**	**43**
		URS 2012	M	335	249	10	47	48
			F	119	96	3	11	20
			Total	**454**	**345**	**13**	**58**	**68**
		AAL 2013	M	348	258	26	86	36
			F	80	40	8	20	20
			Total	**428**	**298**	**34**	**106**	**56**
		LRH 2015	M	382	122	10	144	106
			F	133	39	4	49	60
			Total	**515**	**161**	**14**	**193**	**166**

Table 1. Peak adult GCN counts detected by torchlight survey at: the ACA, Gartcosh, North Lanarkshire, prior to translocation (Knowles & Bates, 2003) in 2004 – 2006; GNR following translocation between 2006 – 2015 as surveyed by Heritage Environmental Ltd (HEL, 2006-2009), URS Corporation Ltd (URS, 2010-2012), Acorna Associates Ltd (AAL, 2013), and LRH (2015). GCN male and female counts in the ACA from 1998 – 2003 are unknown thus only total adult counts are given. GCN male and female counts in GNR are given per zone in addition to total adult count. Summed counts from Kellett & Bates (2006) following translocation completion are also given, where SS counts were included in BB counts. These summed counts represent actual translocated adults, not torchlight counts. SS ponds were not recorded separately from BB ponds until 2006. Total adult counts per zone are given in addition to total counts for GNR.

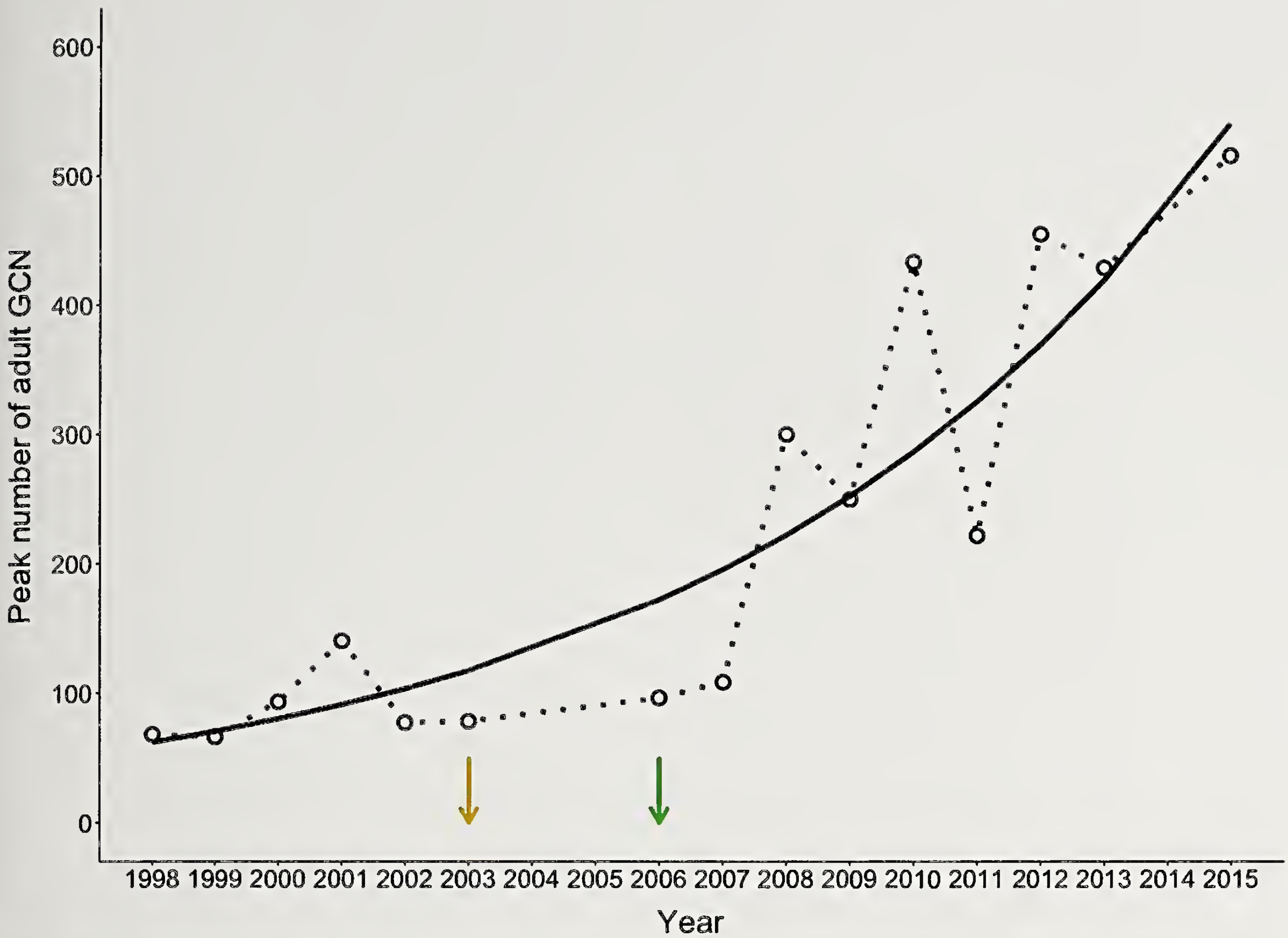

Fig. 3. GCN adult counts between 1998 – 2015 before and following translocation from the ACA to GNR. The orange arrow indicates the end of pre-translocation data whilst the green arrow indicates the start of post-translocation data. No torchlight monitoring occurred during 2004, 2005, or 2014. Adult counts from 2006 – 2015 are from ponds within GNR that contain the translocated population of GCN. The observed (dotted line) and predicted (solid line) adult counts were highest in the last year of post-translocation monitoring in 2015.

Population size throughout entire monitoring period

Year positively influenced adult counts (GLM: F_{13} = 66.681, P < 0.001, R^2 = 81.50%) over the entire monitoring period for GCN (1998 – 2003, 2006 – 2013, 2015), thus this relationship is supportive of growth in adult numbers over time pre- and post-translocation (Fig. 3). Population size in each zone of GNR (Appendix 3) was classed using criteria based on adult counts (small ≤ 10 adults, medium 11-100 adults, large >100 adults) from English Nature (2001). Each zone possessed medium or large subpopulations in 2015 compared to small or medium subpopulations post-translocation in 2006 (McNeill, 2010). Notably, RJ was medium prior to 2015 but is now large. Although RJ is isolated from other zones within GNR, counts have gradually increased from 2006 – 2013, after which the number of adult GCN tripled in 2015. Alongside RJ, GQ has also increased steadily. Indeed, both GQ (193 adults) and RJ (166 adults) exceeded BB in 2015. Prior to 2015, BB possessed the highest adult counts but numbers have been decreasing since 2012. Adult counts in SS remain low and have decreased since 2013.

Adult counts within GNR zones over post-translocation monitoring period

Year positively influenced adult counts within all four zones (GLM: F_{34} = 31.064, P < 0.001, R^2 = 12.78%), thus this relationship confirms growth in adult numbers over time in GNR zones (Fig. 4a).

Difference in adult counts between zones of GNR (post-translocation)

Zone had a significant effect on adult counts (GLM: F_{31} = 47.301, P < 0.001, R^2 = 57.30%). The following values reported for each zone in addition to p-value are the linear estimate ± standard error. Significant negative correlations were observed between adult counts and BB (-430.178 ± 63.152, P < 0.001), GQ (-0.944 ± 0.232, P < 0.001), RJ (-1.173 ± 0.233, P < 0.001) and SS (-3.306 ± 0.265, P < 0.001). A Tukey's post-hoc test was conducted; differences between the means of all zones were significant (P < 0.01), excluding the mean difference between RJ and GQ (P > 0.05) (Fig. 4b). The greatest difference was observed between SS and BB.

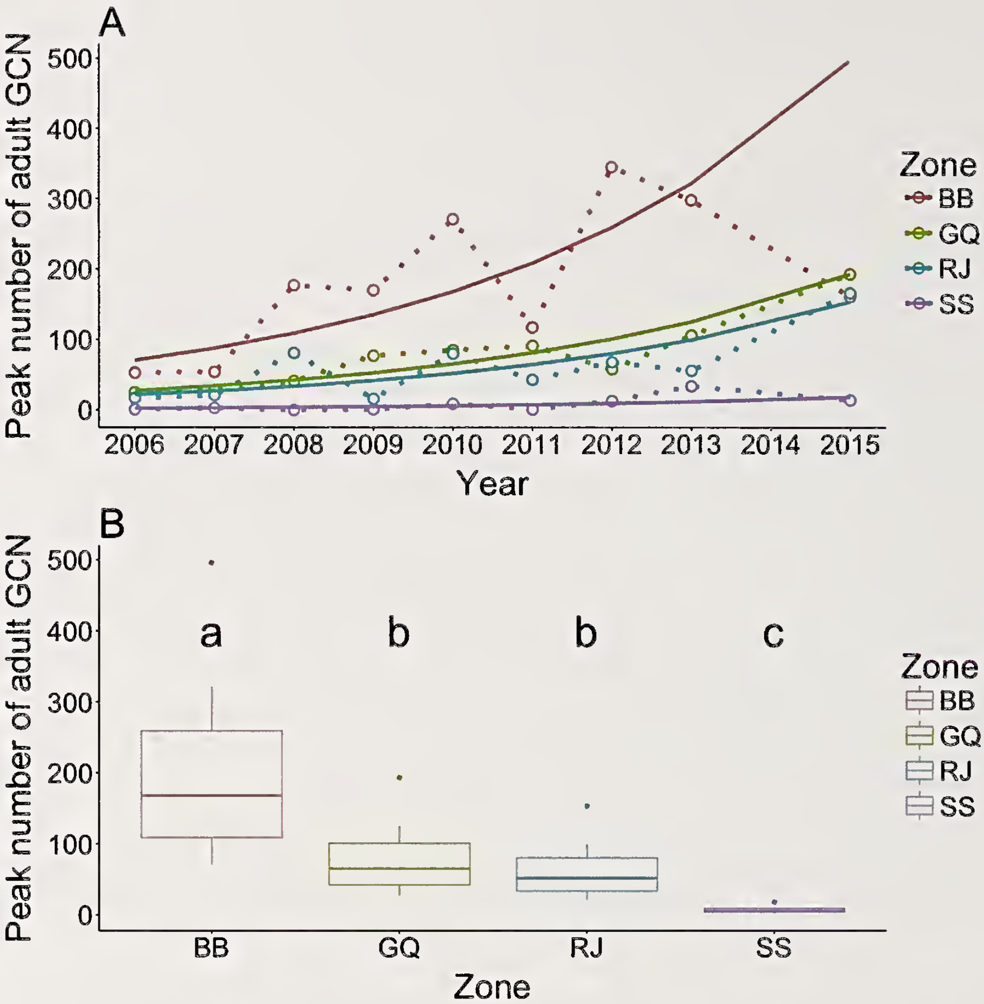

Fig. 4. Variation in GCN adult counts over **(a)** post-translocation monitoring period (2006 – 2013, 2015) in GNR zones and **(b)** between GNR zones. In Fig. 4a, dotted lines show observed GCN counts; solid lines show trends generated by the GLM. BB counts were highest every year except 2015, when GQ counts exceeded all other zones. RJ has increased steadily but SS counts remain consistently low. In Fig. 4b, the results of the Tukey's post-hoc test are shown. The boxplots represent the distribution of adult counts recorded each year in each GNR zone. The median (line), lower and upper quartiles (lower and upper box), and minimum and maximum (whiskers) adult counts are displayed for each box. Differences between the mean peak adult count of all zones were significant ($P < 0.01$), excluding the mean difference between RJ and GQ ($P > 0.05$). Significance is denoted by letters, where different letters indicate a statistically significant difference between the mean adult counts of zones.

DISCUSSION

Post-translocation monitoring has shown that peak counts of GCN adults within the GNR have increased five-fold in the 10 years since translocation from the original ACA; thus the translocated population appears to be flourishing on the basis of adult counts. This contrasts with a recent study by Lewis *et al.* (2016) who found populations at mitigation sites in England had declined, resulting in extinction at 4/18 sites. However, our study corroborates results of Gustafson *et al.* (2016) who captured a number of GCN individuals seven years post-translocation comparable to the number originally translocated. Low counts recorded in 2006 and 2007 may have been post-translocation fluctuations as GCN adults are philopatric to breeding sites and individuals may have migrated back to the pre-translocation site (McNeill, 2010; Gustafson *et al.*, 2016). A decline was observed in 2011 but GCN populations are subject to natural fluctuation (Gustafson *et al.*, 2016) and have been speculated to cycle every four years (Arntzen & Teunis, 1993; Cook, 1994; Skei *et al.*, 2006; McNeill, 2010). Data from GNR zones in 2015 may support this natural cycling as BB counts declined four years on from 2011. Nevertheless, the population remains the largest in Scotland (O'Brien, 2016) with 515 adults recorded by LRH in 2015. English Nature (2001) recommended peak adult counts instead of density as a method of population assessment for GCN as small populations can exist at high density and vice versa (Sewell *et al.*, 2013). Lewis *et al.* (2007) demonstrated that there is high concordance between both methods of population assessment. However, peak adult counts are best supported where counts have been taken early and late in the GCN breeding season to reveal 'true' peaks rather than 'false' peaks as a result of poor timing of torchlight survey (Sewell *et al.*, 2013). Torchlight survey reportedly produces a minimum estimate (6-23%) of population size (Griffiths & Inns, 1998): on this basis, the 2015 GNR population (2,239 – 8,583 adults) has vastly exceeded the number originally

translocated (1,012 adults). Conversely, following translocation of a known number of 1,012 GCN adults to the new GNR, adult counts stood at around 100 adults in 2006 and 2007, representing roughly 10% of the population, in the lower half of Griffiths and Inns' (1998) range.

A male bias has been observed consistently in peak adult counts since post-translocation monitoring began in 2006; prior to this the population had a 1:1 ±10% sex ratio (McNeill, 2010). This may result from detection bias, with male activities making them easier to observe. Males defend lekking areas in ponds to perform breeding displays to attract females (McNeill, 2010; Beebee, 2015) and are more morphologically distinct than females due to characteristic dorsal crests and white-striped tails that reflect torchlight (Langton *et al.*, 2001; Edgar & Bird, 2006). Detection bias can be investigated through Capture-Mark-Recapture (CMR) but this takes several years (Kröpfli *et al.*, 2010). Alternatively, bottle trapping is unbiased towards sex and can obviate detection bias (Griffiths & Inns, 1998). However, welfare issues and time required for trap deployment and checks must be taken into consideration (Gent & Gibson, 1998; Sewell *et al.*, 2013).

Substantial changes in adult counts across all four GNR zones occurred during 2006 – 2015. While BB and SS experienced declines, GQ and RJ counts have increased. There are two plausible hypotheses as to why these changes have occurred and we will discuss support for each. One hypothesis is dispersal within GNR; the other is source-sink dynamics. Amphibian fencing and walls, designed to prevent migration between zones of GNR, were in place from the start of post-translocation monitoring (McNeill, 2010). However, these had been removed in May 2011 prior to torchlight monitoring by LRH in 2015. Consequently, there were no longer any physical barriers to exchange between GCN in different zones of GNR. Indeed, GCN were observed by LRH outside of RJ zone in 2015 and they had traversed the only wall that might contain GCN in this particular zone. Given the capability of adult GCN to disperse up to 1.6 km (Edgar & Bird, 2006; Beebee, 2015; Haubrock & Altrichter, 2016), exchange between zones is highly plausible. A study on dispersal of GCN within and outside GNR would be beneficial in understanding the dynamics of this population and its long-term viability. Connectivity between zones within GNR, and populations external to GNR, is crucial for enhanced genetic exchange and recruitment to this population. SS counts remained consistently low over nine years; thus, these small ponds may be unfavourable for GCN. Water levels of SS1 and SS3 dropped considerably in 2015 (observation by LRH). Created ponds that fail to hold water due to inadequate design or maintenance can result in extinction of GCN populations (Lewis *et al.*, 2016). Therefore, the entire SS zone may require modification to encourage and support GCN (advised pond management for GCN is given by Langton *et al.*, 2001) as these ponds may aid dispersal of GCN between zones BB and GQ now that fences have been removed (McNeill, 2010).

The alternate hypothesis to that of dispersal between zones of GNR is simultaneous extinction and colonization of ponds i.e. source-sink dynamics (Griffiths *et al.*, 2010). Fundamentally, "sinks" are poor quality habitat that cannot support GCN without connectivity to other ponds and where a population therefore goes extinct. However, if individuals continually migrate from "source" or good quality ponds to sinks, sinks can persist indefinitely. Ponds in GNR may have developed into sinks in the years following translocation (e.g. SS ponds). Although an even sex ratio of GCN adults was broadly established across all zones of GNR by translocation completion, torchlight counts in 2006 and 2007 indicated the number of adult GCN in all zones was below the recommended minimum viable breeding population size, in terms of both females and adults (Halley *et al.*, 1996; Griffiths & Williams, 2001). In 2008, BB surpassed this threshold but adult counts in other zones remained low and unpromising for long-term breeding viability. Additionally, RJ is isolated from other zones and consequently, ponds may have low genetic and population viability (Edgar & Bird, 2006; Lewis *et al.*, 2013). It is important for GNR population survival to identify additional sources of recruitment. The nearest source population is Drumcavel Quarry (McNeill, 2010; McNeill *et al.*, 2012), approximately 1 mile north of GNR across a major motorway. Connecting these two populations, and improving connectivity between GNR ponds using corridors to enable juvenile and adult dispersal, is necessary to increase recruitment and genetic diversity. Given recent road and housing developments, and the pre-existing railway line, this may be challenging to implement. In England, Lewis *et al.* (2013) found GCN were lost from mitigation sites where roads interfered with possible migration paths. Nonetheless, improved connectivity may be the only way to ensure North Lanarkshire GCN populations function as a successful metapopulation. However, Halley *et al.* (1996) found even large populations (ponds with over 100 females located more than 3km from a source) have little chance of surviving 20 generations.

Crucially, we have only adult count data to infer translocation success of the Gartcosh GCN population. Monitoring of all life stages was performed by DCM during her research from 2006 – 2008 and the relationship between breeding success and adult presence tested (McNeill, 2010). Breeding adult counts were high in most ponds but egg, larvae and metamorph counts suggested breeding failure. Furthermore, peak larval counts did not correspond to peak adult counts thus high adult counts do not

indicate many breeding adults and subsequently breeding success. This detailed assessment of population viability was not continued in monitoring from 2007 – 2015, where only adult counts were recorded. It is essential that future monitoring incorporate all life stages as presence of one life stage does not reliably indicate presence of others or provide information on long-term recruitment (McNeill, 2010). Furthermore, whilst adult counts appear to indicate the population is thriving, GCN adults can live as long as 14-16 years (Hagstrom, 1979; Francillon-Veillot *et al.*, 1990; Gustafson *et al.*, 2016; O'Brien, 2016). Adults observed during torchlight survey in 2015 could be the same adults originally translocated, which leaves room for doubt as to whether developmental stages are surviving to adulthood. McNeill (2010) found some evidence of recruitment using CMR, as all adults originally translocated to GNR were photographed and adults recruited within GNR were not amongst these records. However, the situation in years following completion of McNeill's study in 2010 is unknown. Given our population estimate based on peak adult counts in 2015, we believe recruitment has continued to occur within GNR. Nonetheless, CMR is essential to confirm the population consists primarily of new adults in all zones and absence of adults originally translocated to GNR. CMR requires long-term study (Kröpfli *et al.*, 2010) and consequently incurs financial cost and substantial investigator effort. Thus it is clear why torchlight survey retains its appeal as a cost-effective and time-efficient monitoring tool. Nonetheless, annual torchlight monitoring of GCN at Gartcosh can only continue with licensed volunteers from local amphibian groups or environmental consultants contracted by NLC.

All literature reviews of translocation emphasise problems encountered by lack of long-term monitoring and failure to produce final reports. Importance of long-term monitoring to determine translocation success was also emphasised by Gustafson *et al.* (2016) in their study of GCN translocation in Sweden. The Gartcosh GCN translocation was an excellent opportunity to understand the potential and flaws of translocation. This Scottish case study appears to provide evidence for success of translocation as a mitigation method in the UK. However, we would suggest cautious interpretation of the torchlight count data. Although 10 years of post-translocation monitoring data exist, they only show the adult life stage. Adult counts indicate population increase but Gartcosh GCN are at risk of becoming a relic population if breeding and subsequent recruitment are not facilitated through continued habitat management and conservation effort. Since the study by McNeill (2010), recruitment has not been confirmed within GNR. Furthermore, although changes within zones are suggestive of dispersal within GNR, routes of dispersal between zones of GNR and sites external to GNR for population exchange remain unidentified. Consequently, we recommend future studies on breeding and dispersal in this population and connectivity between sites. Future management should improve existing ponds (e.g. SS) within the nature reserve to prevent drying out and to maintain ponds at different states of succession to provide varied habitat for GCN (Gustafson *et al.*, 2016). Addition of new ponds between zones is necessary to maintain and improve connectivity between zones, such as GQ and RJ. This is vital with the forthcoming addition of an access road through the nature reserve to a new housing development (*pers. comm.* Pardeep Chand, NLC), which could seriously impact this population. This development alone should imply investment in further monitoring.

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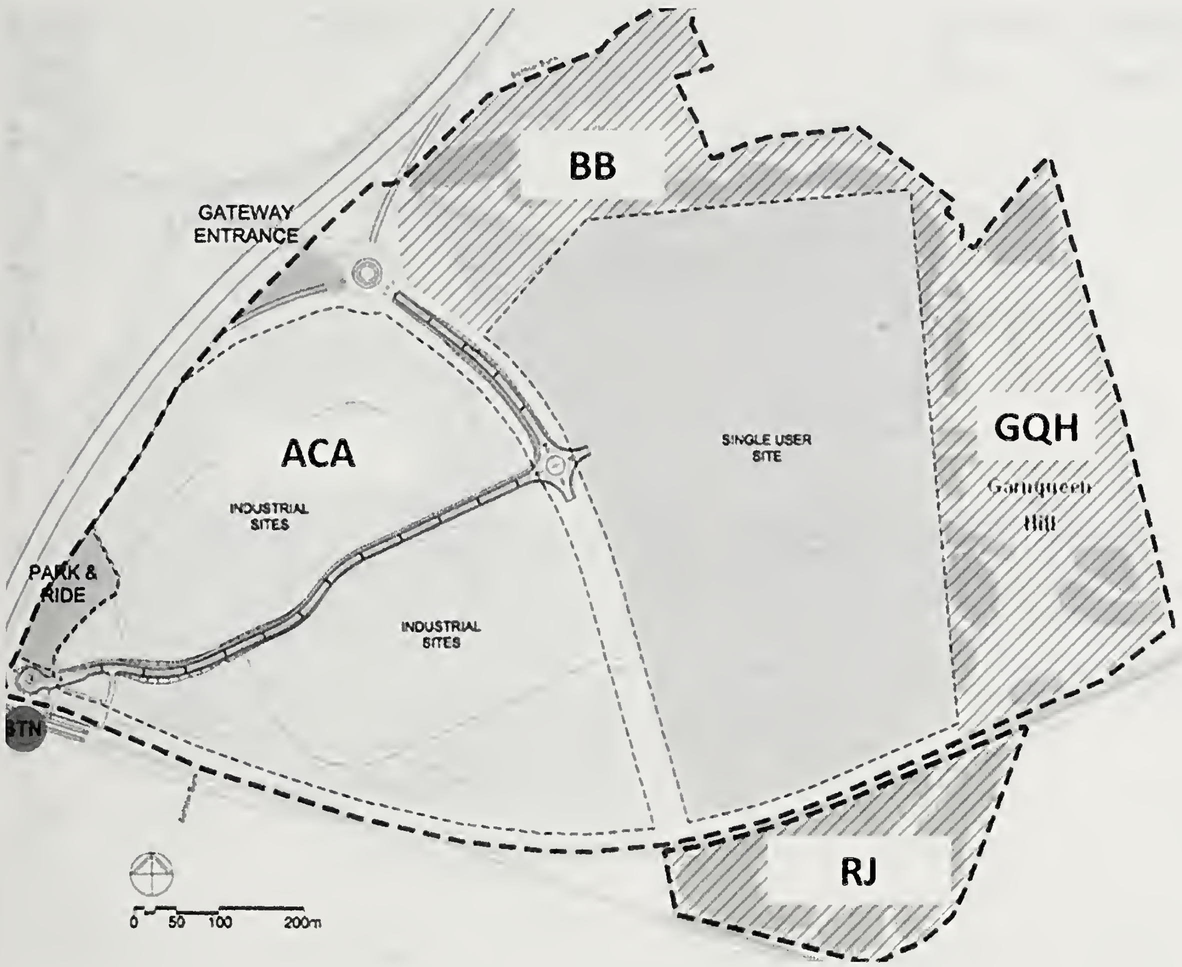
Appendix 1 Map of Gartcosh Industrial Site, North Lanarkshire. The donor site, Amphibian Conservation Area (ACA), is shown in relation to the receptor site, Gartcosh Nature Reserve. The reserve is indicated by hatched lines. Three zones within the nature reserve, Bothlin Burn (BB), Garnqueen Hill (GQH) and Railway Junction (RJ), are shown but the fourth (Stepping Stone) is not shown (see Fig. 1 in main text). This figure was produced by McNeill (2010) after being modified from a map produced by Scottish Enterprise.



Appendix 2.

GCN Survey Form

Surveyor details

Name of surveyor(s)	1.	2.
3.	4.	5.
6.	7.	8.

Pond location details

Site name	
Location name (taken from nearby hamlet/ farm/house/ woodland etc)	
Pond full grid reference	

Habitat suitability factors (refer to HSI guidance and summary notes below)

HSI Visit Date	24/05/13	Score	SI value
1. Map Location. Score: A (optimal), B (marginal) or C (unsuitable).			
2. Pond area in m^2. Estimate.			
3. Number of years in ten pond dries up. Estimate or ask landowner.			
4. Water quality. Score: 1 = bad, 2 = poor, 3 = moderate, 4 = good.			
5. Percentage perimeter shaded (to at least 1 m from shore). Estimate.			
6. Waterfowl impact. Score: 1 = major, 2 = minor, 3 = none.			
7. Fish presence. Score: 1 = major, 2 = minor, 3 = possible, 4 = absent.			
8. Number of ponds within 1 km (1: 25 0000 maps) not separated by barriers to dispersal.			
9. Terrestrial habitat. Score: 1 = none, 2 = poor, 3 = moderate, 4 = good.			
10.Percentage of pond surface occupied by aquatic vegetation (March-May). Estimate.			
HSI Score			
Pond pH			

Water quality Bad = clearly polluted, only pollution-tolerant invertebrates, no submerged plants; Poor = low invertebrate, diversity, few submerged plants; Moderate = moderate invertebrate diversity; Good = abundant and diverse invertebrate community.
Waterfowl impact Major = severe impact of waterfowl i.e. little or no evidence of submerged plants, water turbid, pond banks showing patches where vegetation removed, evidence of provisioning waterfowl; Minor = waterfowl present, but little indication of impact on pond vegetation, pond still supports submerged plants and banks are not denuded of vegetation; None = no evidence of waterfowl impact (moorhens may be present).
Fish presence Major = dense populations of fish known to be present; Minor = small numbers of crucian carp, goldfish or stickleback known to be present; Possible = no evidence of fish, but local conditions suggest that they may be present; Absent = no records of fish stocking and no fish revealed during survey(s).
Terrestrial habitat None = clearly no suitable habitat within immediate pond locale; Poor = habitat with poor structure that offers limited opportunities for foraging and shelter (e.g. amenity grassland); Moderate = offers opportunities for foraging and shelter, but may not be extensive; Good = extensive habitat that offers good opportunities for foraging and shelter completely surrounds pond e.g. rough grassland, scrub or woodland.

- Life stage: Adult = adult, Imm = frog/toadlet or young newt, Larva = newt tadpole or frog/toad tadpole, Egg = newt egg/ frogspawn clump/ toadspawn strings
- Provide counts of adults, immatures and spawn clumps/ strings but indicate detection of eggs and larvae with a tick
- Water clarity 1 = good, pond bottom visible, 2 = intermediate, bottom visible in shallows, 3 = turbid, bottom not visible
- Rainfall 0 = none, 1 = yesterday, 2 = immediately prior, 3 = during daytime survey, 4 = during night survey (i.e. torch survey).

Visit 1	Number / life stage						Date (dd/mm/yy)	
Species (GCN, smooth, palmate, toad, frog)	Adult			Length (mm)	Larva	Egg	Survey Time (24h)	to
	M	F	Unk				Air temp (°C)	
							Water clarity (1-3)	
							Water temp (°C)	
							Water pH	
							Conductivity	
							Rainfall (0, 1, 2, 3,4)	
							Wind disturbing water (tick)	
							Bright moonlight (tick)	
							% shoreline searched	
							Notes:	

Visit 2	Number / life stage						Date (dd/mm/yy)	
Species (GCN, smooth, palmate, toad, frog)	Adult			Lmm	Larva	Egg	Survey Time (24h)	to
	M	F	Unk				Air temp (°C)	
							Water clarity (1-3)	
							Water temp (°C)	
							Water pH	
							Conductivity	
							Rainfall (0, 1, 2, 3,4)	
							Wind disturbing water (tick)	
							Bright moonlight (tick)	
							% shoreline searched	
							Notes:	

Visit 3	Number / life stage						Date (dd/mm/yy)	
Species (GCN, smooth, palmate, toad, frog)	Adult			Lmm	Larva	Egg	Survey Time (24h)	to
	M	F	Unk				Air temp (°C)	
							Water clarity (1-3)	
							Water temp (°C)	
							Water pH	
							Conductivity	
							Rainfall (0, 1, 2, 3,4)	
							Wind disturbing water (tick)	
							Bright moonlight (tick)	
							% shoreline searched	
							Notes:	

Visit 4	Number / life stage						Date (dd/mm/yy)	
Species (GCN, smooth, palmate, toad, frog)	Adult			Lmm	Larva	Egg	Survey Time (24h)	to
	M	F	Unk				Air temp (°C)	
							Water clarity (1-3)	
							Water temp (°C)	
							Water pH	
							Conductivity	
							Rainfall (0, 1, 2, 3,4)	
							Wind disturbing water (tick)	
							Bright moonlight (tick)	
							% shoreline searched	
							Notes:	

The survey form was designed by Erik Paterson (Jacobs UK Ltd), a licenced ecological consultant, and developed by LRH for purposes of this study.

APPENDIX 3

Nature Reserve Zone / Pond		Torchlight Survey 1			2			3			4			5		
		GCN			GCN			GCN			GCN			GCN		
		M	F	Un	M	F	Un	M	F	Un	M	F	Un	M	F	Un
Bothlin Burn (BB)	BB1	18	2	0	9	0	0	17	5	0	4	2	0	0	1	0
	BB2	28	1	0	11	2	0	21	4	0	1	0	0	0	0	0
	BB3	14	2	0	5	0	0	12	5	0	4	1	0	2	1	0
	BB4	26	2	0	9	2	0	19	4	0	5	3	0	0	0	0
	BB5	20	1	1	11	1	0	0	0	0	5	0	0	0	0	0
	BB6	0	0	0	0	1	0	3	3	0	1	1	0	3	4	0
	BB7	16	3	0	19	12	1	11	10	0	10	6	0	12	6	0
	BB8	0	0	0	7	2	1	11	8	0	9	3	0	9	5	0
Stepping Stone (SS)	SS1	5	0	0	1	0	0	1	0	0	0	1	0	0	1	0
	SS2	3	0	0	2	3	0	0	1	0	0	0	1	0	2	0
	SS3	2	1	0	1	1	0	0	0	0	0	2	0	0	1	0
Garnqueen Hill (GQ)	GQ1	3	0	0	2	0	1	0	0	0	1	1	0	0	0	0
	GQ2	13	2	0	7	2	0	0	1	0	1	1	0	1	3	0
	GQ3	27	5	0	24	12	0	42	12	0	10	2	0	27	8	0
	GQ4	34	6	0	26	11	1	35	15	0	6	1	0	6	2	0
	GQ5	29	12	0	24	11	0	21	9	0	18	8	0	15	5	0
	GQ6	29	2	0	30	9	0	11	5	0	6	5	0	2	2	0
	GQ7	9	0	0	7	4	0	8	2	0	10	1	0	7	3	0
Railway Junction (RJ)	RJ1	25	1	0	16	8	1	5	5	0	15	5	0	3	1	0
	RJ2	21	6	0	8	4	0	6	4	0	5	4	0	1	1	0
	RJ3	5	2	0	6	1	0	14	7	0	9	10	0	3	0	0
	RJ4	19	8	0	29	11	0	13	6	0	18	12	0	11	6	0
	RJ5	14	10	0	23	11	2	32	15	0	11	15	0	1	2	0
	RJ6	22	9	0	15	13	0	22	12	0	17	14	0	4	3	0
Total		**382**	75	1	292	121	7	304	**133**	0	166	98	1	107	57	0
		458			420			437			265			164		

Summary of GCN adults recorded on all five torchlight surveys at each pond in GNR during 2015. Sex of individuals are given. Peak male and female adult counts are highlighted in bold. Peak counts were recorded as the highest adult count obtained for each sex in across all ponds in GNR during torchlight surveys in 2015.

Zone	2006	2007	2008	2009	2010	2011	2012	2013	2015
BB	Med	Med	Large	Large	Large	Large	Large	Large	Large
	53	54	177	170	271	117	345	298	161
SS	-	Small	NA	Small	Small	Small	Med	Med	Med
	-	3	0	1	9	1	13	34	14
GQ	Med	Med	Med	Med	Med	Med	Large	Large	Large
	25	28	41	77	85	91	131	106	193
RJ	Med	Med	Med	Med	Med	Med	Med	Med	Large
	17	21	81	16	80	43	68	56	166

GCN adult counts and population size classes for each zone in GNR. Using peak adult counts, populations are classified as small (≤ 10), medium (11-100), or large (>100), using criteria from English Nature (2001). In 2006, counts were not recorded separately for SS and were included in counts for BB.

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Natural history contributions of the University of Glasgow Exploration Society to Scotland and the World

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ABSTRACT
Expeditions with a natural history focus have been organised by University of Glasgow staff and students since the 1930s. The educational benefits of such expeditions to students have been reported by Harper *et al.* (*Journal of Biological Education* 51, 3-16; 2017). Here, we present a short history of these expeditions, concentrating on their scientific achievements. In addition to expedition reports, a large number of PhD theses, masters and honours project reports and scientific papers have been based on expedition work. Many biological specimens have been deposited in museums, including some new species. We provide case histories of four expedition locations, to demonstrate the variety of work done, and the value of returning many times to the same place: Scotland, Trinidad and Tobago, North Cyprus and Ecuador. A major problem for expeditions is funding. For many years, the Carnegie Trust for the Universities of Scotland ran a funding stream that was crucial to the viability of Scottish university expeditions, but this has sadly now closed. For Glasgow University expeditions, the Blodwen Lloyd Binns Bequest has provided a reliable source since 1994, and we hope that it will continue to do so.

INTRODUCTION

The first University of Glasgow staff-student expeditions with a natural history focus that we know of were to the inner Hebridean island of Canna in 1936 and 1937 (Table 1A). After a hiatus of a dozen years, partly explained by the Second World War, the next such expedition was to the Garvellach Islands in 1949 and then to St. Kilda in 1956. Thereafter, one or two expeditions took place most years until the early 1980s (Table 1). Initially, these expeditions were organised by interested groups of staff and students, who applied to the University Court for approval and financial support, and to external sources, especially the Carnegie Trust for the Universities of Scotland (hereafter, Carnegie Trust). In 1959, the Carnegie Trust instituted a specific funding stream for University Expeditions (Walker, pers. comm.). Another important funding source that began around the same time was the Royal Geographical Society's expedition grant scheme (1956).

We have not been able to locate any documents relating to the foundation of the University of Glasgow's Exploration Society (GUExSoc), but the first expedition reports held by the University Library which acknowledge the existence and support of GUExSoc are for Finland (1970) and Calabria (1970), and we were told that Morocco (1970) was also organised through GUExSoc (Hansell, pers.comm.).

Some of the expeditions in the late 1960s to early 1980s were essentially field research trips for the final year class in Topographic Science, aimed at gathering data for final year dissertations. Although the Carnegie Trust initially supported these under the University Expeditions scheme, they later took the view that Universities should fund dissertation work themselves. Later Topographic Science expeditions such as Maam, 1978 and Inchnadamph, 1979 (Table 1) therefore received no Carnegie funding.

Membership and equipment lists and accounts survive for the early years of GUExSoc, 1972-1982. Membership averaged about 30 per year and cost £0.25. The Society had an equipment store mainly comprising tents and other camping equipment. Excluding the Topographic Science field trips, an average of two expeditions per year occurred over that period.

In 1988 after a few years of inactivity, GUExSoc was re-constituted with the full support of the University Principal at that time, Sir Alwyn Williams, and the University Court, and, crucially, with a new funding procedure. The 1988 settlement established a new body, the Exploration Council, technically a sub-committee of Court and composed of a small number of senior staff with relevant interests. As first chair of the Council, Ian Thomson, Professor of Geography, steered this new arrangement through its initial years.

Year	Location	Themes and Outcomes
A) Scotland		
1936, 1937	Canna (Inner Hebrides)	+ Geology, ecology, zoology. Published papers on natural history of Canna and Sanday (Bertram, 1939), birds of Canna (Carrick & Waterston, 1939), and parasites of birds and mammals (Carrick, 1939). Also a report on expedition provisioning (Blair, 1936)
1949	Garvelloch Isles (Inner Hebrides)	Geology, zoology. Six published papers on marine lamellibranchs (Hunter, 1951), geology (Hunter & Muir, 1954), insects (Muir, 1954), birds (Dunn *et al.*, 1954), ecology (Hunter, 1954) and molluscs (Hunter, 1953)
1956	St. Kilda (Outer Hebrides)	# Zoology (two papers: Hamilton (1963), Fraser *et al.*,1957)
1962, 1964	South Uist (Outer Hebrides)	+ Zoology. Insect specimens collected
1974	Callanish, Lewis (Outer Hebrides)	* Geography (TS)
1975, 1976	Durness (Sutherland)	* #Zoology, Botany. The full report for 1975 exists; for 1976, only a hand-written plant list
1976	Scourie (Sutherland)	*Geography (TS)
1979	Inchnadamph (Sutherland)	* Geography (TS)
1980	South Uist (Outer Hebrides)	~ Carnegie funded; no other record
1980, 1982	Foula (Shetland)	# Bird ringing and other data collection (several papers built on data collected, notably Furness, 1981; Furness Todd, 1984
B) Beyond Scotland		
1963	Narvik (Norway)	*Geography
1964	La Causse du Larzac (France)	*Geography
1965	Austria	*Geography
1965, 1966	Iceland	Geography. Glacier mapping
1966	Portugal	+ Zoology (fish, entomology); book chapter by Miller (1986)
1966	Yugoslavia	* Geography
1969	Norway	* Geography (TS)
1970	Morocco	# Zoology
1970	Finland	# Geography (TS)
1970	Calabria (southwest Italy)	* Geography (TS)
1971	Valais (Switzerland)	* Geography
1972	Iceland	* Zoology and Geology
1973	Grimsel Pass (Switzerland)	Geography (glacier mapping)
1973	Morocco	~ Carnegie funded; no other record
1974	Finland	* Geography
1975	Czechoslovakia	~Carnegie funded; no other record
1975	Pyrenees	~Carnegie funded; no other record
1977	Pyrenees	~Talk given and Carnegie funded
1977	Seychelles	Zoology. Report may be lost. Two research papers on fairy terns (Houston,1979), and skinks (Brooke & Houston, 1983)
1978, 1980	Maam (Finnish Lapland)	* Geography (TS)
1978	Corsica	* Geography
1979	Faroe Islands	~Carnegie funded; no other record
1980-81	Crete	~Carnegie funded; no other record
1982	Cwm Idwal (Wales)	* Geography (TS)
1983	Newborough Warren (Wales)	* Geography (TS)

Table 1. University of Glasgow Expeditions 1936-1983. Usage of * denotes report in University of Glasgow Library; + denotes specimens deposited in the Hunterian Museum; TS denotes Topographic science class field trips; ~ denotes expeditions known only from the records of the Carnegie Trust for the Universities of Scotland or from GUExSoc minutes books.

Year	Number and Years	Themes
a) Scotland		
Islay (inner Hebrides)	Three: 2014-16	+ Zoology
b) Europe		
Azores	Two: 1989, 2003	Ornithology
North Cyprus	Eight: 1992-98	+ Marine turtle conservation/biology; feral donkeys
Cyprus (RAF Akrotiri)	Fourteen: 2000-16	Marine turtle conservation/biology
Iceland	Eighteen: 1992-2002 and 2008-16	First series: glaciology; second series: wildlife biology/conservation
Spitzbergen	1996 only	Geography
c) Africa		
Canary Islands	Two: 2000, 2016	Geology
Egypt	Five: 1990; 2013-16	First, mainly geography, plant ecology; later series ecology
Gambia	Four: 2005-08	Animal welfare, zoology
Kenya	Two: 1998, 2016	First, zoology; more recent, sustainable development
Seychelles	1996 only	Zoology
Tanzania	Eight; 1991, 1998, 2008-15	Mainly geographical, but also zoology
Zambia	Two; 2006, 2008	Aquatic plant ecology, zoology
d) Asia		
Borneo	1999 only	Zoology
Himalayas	1993 only	Geography
Kazakhstan	1998 only	Ornithology
Oman	1990 only	Ornithology
e) Australasia		
Kimberley (Australia)	1996 only	Geography
Tutamoe (New Zealand)	1995 only	Geography
f) North America		
Canada	1997 only	Wildlife conservation
g) South America and the Caribbean		
Bolivia	Eleven: 1998-2016	+ Zoology, ornithology
Brazil	Three: 1999-2003	Aquatic plants, zoology
Costa Rica	2005 only	Zoology
Ecuador	Twelve: 1997; 2000-2012	+ Zoology, ecotourism development
Guyana	1995 only	+ Zoology
Peru	Seven: 2006-2015	Zoology
Trinidad and Tobago	Thirty five expeditions: 1989-2016: two to T and T; 20 to Trinidad alone; 13 to Tobago alone	+ Zoology, some plant ecology, geology

Table 2. University of Glasgow Expeditions 1989-2016. Usage of + denotes specimens deposited in the Hunterian Museum; reports for most expeditions are available in the University Library and/or on the GUExSoc web-site; we have not attempted to collate the large number of publications resulting from these expeditions; see the text, especially the case histories.

Council was given an annual budget and the task of overseeing the activities of GUExSoc, especially of scrutinising expedition proposals, deciding whether or not to approve them, and then deciding on the level of funding to provide. GUExSoc itself began afresh in 1988 with a new constitution. The first of the new era of expeditions took place in 1989 (Table 2: Trinidad and Tobago; Azores). The constitution made clear that the main aim of expeditions should be the advancement of science; approval and support would not be given to proposals that simply involved adventurous travel.

The conditions of funding from the Carnegie Trust were important to all Scottish Universities which organised expeditions. The Trust's rules were that expeditions should mainly be for undergraduate students with staff providing support and training; that the sponsoring University should provide formal approval of each expedition proposal and some level of financial support; and that work aimed at student dissertations should not be the main purpose of an expedition. Correspondence with the Trust clarified that individual students were not barred from carrying out dissertation research as long as this was not the focus of the expedition as a whole; also that full-time staff presence was not essential. In the early years, Trust grants were a few hundred pounds per expedition; when the scheme ended in 2014, the maximum award was £2K per expedition. Of the seven Scottish Universities which benefitted from Trust expedition grants, GUExSoc was the most active (Table 3).

Glasgow Natural History Society (GNHS) has had an important role in GUExSoc expeditions following the establishment of the Blodwen Lloyd Binns Bequest (BLB) in 1993. The BLB committee agreed in 1994 that undergraduate expeditions were one of the activity categories that would be eligible for support. In the period 1994-2010, the Bequest supported 59 expeditions, granting a total of £33.5K, 22% of its annual grant expenditure (Downie *et al.*, 2012), and a similar level of support (£5K per annum) has continued since then. In addition, GNHS has hosted many talks on these expeditions in its talks programme, and for a few years, *The Glasgow Naturalist* included short reports on BLB funded projects, including expeditions (e.g., Trinidad 2000 in *TGN* 23(6), 2001; Azores 2003 in 24(2) 2004). More recently, summary expedition reports have appeared in the GNHS quarterly newsletter and full reports have been accessible via GUExSoc's web-site (http://glasgowexsoc.org.uk/).

The educational value to students of participating in expeditions has been reported by Downie *et al.* (2008), describing the potential of expeditions for students undertaking final year research projects, and by Harper *et al.* (2017) who emphasise the transferable skills/graduate attainment value of organising and taking part in expeditions. In this paper, we focus on the natural history research outcomes of the long series of expeditions run by GUExSoc. Given the very large number of expeditions organised through GUExSoc, it would be impossible to do justice to them all. We therefore have adopted a case-history approach and present four themes: Scotland, Trinidad and Tobago, North Cyprus, and Ecuador.

EXPEDITION CASE HISTORIES

Scotland

All the earliest expeditions were to Scottish localities, some visited more than once, from the earliest to Canna in 1936 up to Foula in 1980 and 1982 (Table 1A). The first location, Canna plus neighbouring Sanday, was visited in consecutive years and produced high quality results published in peer-reviewed journals (Bertram, 1939; Carrick, 1939; Carrick & Waterston, 1939). These described many aspects of the natural history of the islands: physical geography, botany, terrestrial and freshwater invertebrates, birds and mammals. The impressive range of coverage was the product of the students plus a considerable number of experts who helped identify pre-sorted specimens. Bertram (1939) wrote that 'The original object was to survey an island in the West of Scotland with a view to providing data which would serve as a basis for future ecological studies'. Sadly, the Second World War got in the way of the planned future work. The standard of the directly published outputs from the two Canna expeditions has never been exceeded.

University	Number of grants	Total awards (£: rounded thousands)	Percentage of total awards
St. Andrews	29	£16K	2.9
Edinburgh	106	£125K	23.6
Glasgow	160	£243K	45.9
Aberdeen	83	£77K	14.6
Dundee	25	£29K	5.6
Stirling	15	£12K	2.4
Napier	13	£26K	4.9
Joint SUs	1	£.5K	0.1

Table 3. University expedition grants awarded by the Carnegie Trust for the Universities of Scotland, 1959-2014. Data kindly provided by Professor Andy Walker, Secretary and Treasurer of the Trust.

Twelve students were involved over the two years, mainly zoologists but including two botanists. The expedition's logistics also were published as a guide to future similar endeavours. Blair (1936) noted that an investigation into dietary needs on expeditions would have been of interest but that "one could not risk impairing the members' efficiency by experiments in another sphere of science".

The next expedition was to the Garvellach Isles (1949). This also led to an impressive list of six papers, after some delay (Table 1A). One of the students and authors, David A. Muir, who went on to a career in malaria research, has provided some reminiscences of the expedition, which had the grand title: Scottish Ecological Expedition to the Garvelloch Islands (SEEGI). Note that the name of these islands in English is a version of the Gaelic Garbh Eileaich; in the 1940s this was given as Garvelloch, but more recently as Garvellach; we use the latter spelling here, except for the titles of the original publications. There are some butterfly specimens in the Hunterian Museum with these apparently enigmatic initials on their labels (Muir, 1954, is a short note on the Garvellach insects). The students were accompanied by staff member Bill Russell Hunter, who later had a distinguished career in the USA. Muir provides a piece of doggerel commenting on Hunter's cooking skills:

'Poor Hunter, marooned with his mutinous crew
And all because of his pemmican stew!
He cooked it in secret with weird incantations
And added some nettles to spin out the rations.
He served it up steaming and reeking and rich,
Dark golden in colour and sticky as pitch.
But of course all the 'gannets' with palates of leather
Simply couldn't detect the delectable flavour!
They complained it was gritty and cooked in a hurry
And proceeded to drown it in Worcester and curry.
By this time the Dixie was only half emptied
But the 'gannets' shied clear and refused to be tempted
For only a staunch and redoubtable few
Would dare a repeat of that pemmican stew.
Yes, Hunter concocted many a brew,
But never a one like the pemmican stew!'

St. Kilda (1956) also had published results (Table 1A) but thereafter the main outcomes were expedition reports, descriptive of the projects undertaken. An important purpose of these was to provide funders with prompt accounts of the work achieved, and they remain the only account of most of these activities. The practice of depositing a copy in the University Library began in the 1960s but was not always adhered to (Tables 1 and 2).

The two expeditions to the Shetland island of Foula (1980, 1982) were exceptional, firstly in having participants from several other organisations. Of the 11 members of Foula (1982), six were Glasgow based and the others from Durham, Edinburgh, Peterborough and London. Secondly, these expeditions did have published outputs (Table 1A). In addition, Furness (pers. comm.) reports that these expeditions collected baseline data that contributed to several later papers, notably an important paper in *Nature* by Votier *et al.*(2004), demonstrating the huge value of long-term datasets in ecology.

After a gap of three decades, in response to the needs of students who could not afford the expense of overseas expeditions, and also who planned careers in UK conservation and environmental management, GUExSoc introduced the idea of a 'Remote Scotland' expedition in 2013. This clearly met a need, as many students applied, even though the location was initially undecided. Islay was soon chosen (not, perhaps, particularly 'remote') partly because of the input of the RSPB and also because of correspondence with the Islay Natural History Trust which was enthusiastic about the idea. The 2017 Islay expedition was the fourth in succession. In addition to the normal reports, the expeditions have helped add to the biological records of the island (Fig.1).

Fig. 1. Leaders Lorna Archer and Angus Lothian checking wildflower identification, Islay 2015 (photo credit: Richard Thompson).

Trinidad and Tobago

When GUExSoc was re-constituted in 1988, one of the first expeditions was to Trinidad and Tobago in 1989. Why there? One of us (JRD) had already established a research link in Trinidad and was aware of the potential of the islands as a location for a student expedition. In addition to its under-researched biodiversity, the country was peaceful, relatively small and therefore accessible, English-speaking and mostly free of troublesome tropical diseases. In Trinidad, also, the University of the West Indies (UWI) campus at St. Augustine offered a base with laboratory facilities, should we need them. Even with these advantages, it is unlikely that any of the 1989 participants envisaged that they would be the

first of 35 expeditions spanning (by the end of 2016) 27 years (Table 2).

Looking back, the 1989 expedition was almost recklessly ambitious. The total personnel list included 33 people, a mix of staff, post-graduates and undergraduates, led by Richard Rutnagur, a PhD student with Trinidadian family connections. The expedition worked on both islands with the Trinidad team based near UWI, and the Tobago team split between two locations; marine biologists in the south at Buccoo and botanists in the north at Charlotteville. Funding an expedition of this size was difficult and co-ordinating activities in the days before mobile phones (in a country with a barely functioning telephone system) was more so. Despite these problems, the expedition produced a report of nearly 100 pages, covering the results of a very diverse set of projects: the state of Tobago's coral reefs; regeneration of the Tobago Main Ridge forest following the devastation caused by Hurricane Flora in 1965; the distribution and habits of an endangered endemic bird, the Trinidad piping guan; the nesting activities of leatherback turtles on Trinidad's east and north coast beaches; conservation measures suitable to protect the collared peccary whose populations are heavily affected by hunting; and several projects on the reproductive ecology of Trinidad's frogs.

The second expedition (1991) was similar, also with 33 participants and with work on both islands, generating a report of 123 pages: in Tobago, only on the coral reefs in the south; in Trinidad, more on marine turtles, the piping guan, frog reproduction and new projects on dragonfly territoriality and veterinary aspects of public health, involving vultures and goats.

Thereafter, expedition teams were smaller and based on only one of the islands: 20 more expeditions to Trinidad (1993-2016, almost yearly) and 13 consecutive visits to Tobago (2004-16). Most of the expeditions have included several distinct projects (five on average) with staff and students working together in flexible teams. Table 4 shows the distribution of project themes.

Work on frogs and marine turtles has dominated, reflecting the research interests of the staff members mainly involved. Other themes have often resulted from interactions with local organisations: for example, studies on monkeys and bats arose from requests by the Trinidad Government's Wildlife Section, and marine turtle monitoring on Tobago from 2004 resulted from interactions with local NGOs, Save Our Sea Turtles (SOS) and North East Sea Turtles (NEST). Each expedition has produced a report, available in the Glasgow University Library, with most also available on GUExSoc's web-site (www address: https://glasgowexsoc.org.uk). In addition, five PhD students have carried out their field research in association with Trinidad expeditions, and several Masters students and many undergraduates have undertaken their research projects on the islands. All this research has contributed to over 90 scientific papers in peer-reviewed journals. In addition, the work has contributed to a recent field guide to the reptiles and amphibians of Trinidad and Tobago (Murphy *et al.*, 2017) and to a book chapter on the conservation status of the islands' frogs (Auguste *et al.*, 2017). Some might think this a surprising outcome for work mainly done by undergraduate students, but if such work is properly supervised, there is no reason why it should not produce competent and publishable science, especially from locations holding such an abundance of biodiversity and where basic natural history observations are still needed. One of the pleasing outcomes of the Trinidad and Tobago expeditions is how often they have helped young scientists to achieve their first publications. Of the 90+ papers derived from these expeditions, over 60 of the authors were undergraduates when they did the work (see Downie, 2012 for a complete list of the publications to 2010). In addition, many Trinidad and Tobago expedition participants have progressed to distinguished careers in science. What has all this effort achieved? We present a short selection of highlights.

	Themes
51.1	Frogs: reproductive ecology, behaviour, treefrog adhesion, distribution, new species, phylogeny, conservation
20.9	Marine turtles: nest monitoring and conservation, nesting behaviour and physiology, hatchling behaviour
13.2	Invertebrates: crab behaviour, insect systematics and ecology, corals- fossil reefs and reef conservation
7.1	Birds: diversity, behaviour, ecology
4.9	Mammals: wild pig conservation, monkey behaviour, bat diversity
1.6	Lizards: diversity and behaviour
1.1	Fish: diversity, ecology

Table 4. Distribution of Trinidad and Tobago expedition project themes, from 35 expeditions and 182 projects.

The golden tree frog *Phytotriades trinitatis* (Fig.2) is one of Trinidad's most iconic species. Living in the water tanks enclosed by the leaves of the giant bromeliad *Glomeropitcairnia erectiflora,* this frog is found only near the summits of the island's highest mountains. Using molecular phylogenetic methods, Jowers *et al.* (2008) established that this species should be classed in a genus on its own and that it is not closely related to frogs in the genus *Phyllodytes* to which it was previously assigned. More recently, Brozio *et al.* (2017) have established the value of the new method of environmental DNA for detecting these frogs without having to destroy their host plants. Monitoring the health of the golden tree frog population should be much easier in future.

Fig. 2. The golden tree frog, *Phytotriades auratus*, El Tucuche, Trinidad (photo credit: Gillian Simpson).

Before our work, the stream frog *Mannophryne trinitatis* was considered to occur both in Trinidad and in the nearby Paria Peninsula of Venezuela, and possibly also in Tobago. Manzanilla *et al.* (2007) showed that the Venezuelan and Tobagonian populations belong to different species, confirming *M. trinitatis* as a Trinidad endemic (and the Tobago species *M. olmonae* as a Tobago endemic). In *Mannophryne* species, males guard the eggs on land, then carry the hatched tadpoles to water (Fig.3). Downie *et al.* (2001) showed that transporting males are careful to avoid depositing their tadpoles in water containing predators and that they can carry their tadpoles for several days in search for a suitable pool or stream. An early assessment by IUCN suggested that this species is amongst the frog species threatened with extinction, but our recent results (Greener *et al.*, 2017) show that it is highly abundant and widespread in suitable habitat in Trinidad.

The first two Trinidad expeditions included monitoring of the east and north coast beaches for nesting marine turtles, at the request of the Wildlife Section's director, Dr Carol James. The findings from these expeditions (later written up by Godley *et al.*, 2001a, b) contributed to the discussions between government and local communities that led to the establishment of a set of NGOs whose role was to protect nesting turtles and to educate visitors about them. Our later expeditions have worked with several of these NGOs: at Matura, Grande Riviere, Matelot and Fishing Pond (in Trinidad) and with SOS and NEST in Tobago. Our work has helped clarify the sizes of the nesting populations and to map the beaches where they occur (Walker *et al.*, 2015).

Fig. 3. A male Trinidad stream frog, *Mannophryne trinitatis* transporting his tadpoles (photo credit: Joanna Smith).

Fig. 4. Entomologist Jeanne Robinson sampling from a bromeliad, Arima Valley, Trinidad (photo credit: Geoff Hancock).

Several new species of Diptera (flies) have been named and described as a result of our Trinidad expeditions. The phorid *Megaselia nidanurae* was discovered to lay its eggs in the foam nests of the burrow-nesting frog *Leptodactylus fuscus* (Downie *et*

al., 1995). A new species in the Mycetobiidae, *Mycetobia downiei* was found as larvae in sap runs of mature Saman and Mora trees (Hancock, 2016). Arising from observations made in bromeliads of fly larvae while monitoring the golden tree frog (Fig.4), some projects were planned. Hoverflies were reared from bromeliads and similar phytotelmatus habitat and three new species *Copestylum elizabethae*, *C. louisae* (Rotheray *et al.*, 2007) and *Quichuana longicauda* (Ricarte *et al.*, 2012) were revealed.

North Cyprus

In 1992, the first Glasgow University Turtle Conservation Expedition (GUTCE) to Northern Cyprus took place, in many ways resulting from the Trinidad and Tobago expeditions of 1989 and 1991. Plans to study wild birds on the 1989 Trinidad and Tobago expedition were abandoned at the last minute due to permit issues and instead it was suggested that the group work on marine turtles.

Brendan Godley (BJG) was part of the 1989 team and returned (with ACB) as leader in 1991 to continue the work on marine turtles. Meanwhile, a fortuitous meeting took place in Cyprus in the summer of 1991, between Kutlay Keço, Ian Bell, and Celia Moorley-Bell of the Society for the Protection of Turtles in Northern Cyprus (SPOT), and a friend of University of Glasgow staff members Sally Solomon and Roger Tippett. The need to do more to protect the turtles in Cyprus was discussed, and aware that Sally had conducted research on turtles, the friend suggested that the SPOT team write to Sally to ask if there was a group of students who might come out to Cyprus to help. Knowing that BJG had been involved in monitoring marine turtles in Trinidad and Tobago, Sally passed on the letter and asked BJG if he could get a group of students together to go out to Cyprus in the summer of 1992. The project was born and a group of 14 students, led by BJG and ACB and supported by University of Glasgow staff members including Sally Solomon, Roger Tippett and JRD took part in the first GUTCE expedition.

In 1992, our main base was at the Fire Station in Yesilkoy on the Karpaz peninsula, and as we explored all of the 80+ turtle nesting beaches over the season, we quickly came to realise the importance of Alagadi Beach, situated on the north coast of the island, which was also conveniently where SPOT President Kutlay Keço lived. In that first year we camped on the beach, which was pretty tough after a night shift, trying to sleep in the heat of the day! Over that summer however, Ian and Keço came to the conclusion that we were a hard- working and eager group and asked us to return the following year, generously renovating an old building at Alagadi for us, named the 'Goatshed' (Fig.5) after the previous inhabitants! During the summer of 1993 we came to realise that there was a wealth of research to be conducted on the turtle populations in Cyprus and thanks to Sally's persistence, both ACB and BJG were awarded University of Glasgow post-graduate scholarships to conduct the fieldwork for their PhDs in Cyprus. This amazing opportunity secured the long-term future of the project and formed a platform for both academic careers.

Fig. 5. The turtle team at The Goatshed, main base of the marine turtle project, North Cyprus (photo credit: Annette Broderick).

Although mostly focusing on marine turtles, other studies have been conducted on crabs, frogs, birds, dune vegetation and a separate GU expedition was mounted to study the feral donkeys. The project has continued each year since and is now in its 25th year, although it subsequently moved with BJG and ACB to the University of Swansea (1999) and then Exeter (2003). Now named the Marine Turtle Conservation Project, it is a collaboration with the Society for the Protection of Turtles in Northern Cyprus (SPOT) and the Environment Protection Department and accepts volunteers from all around the world. The Goatshed is still our main base on the island and also now has a small information centre for visitors and local people to come to find out about turtles and if possible arrange to see nesting and/or hatchling turtles.

Overall the project has led, in total or in part, to eight PhD theses, with a further five underway, and has resulted in over fifty peer-reviewed scientific papers. In addition, data from the project have provided the basis for the designation of five Special Environmental Protected Areas (SEPAs) containing turtle nesting beaches. These sites have also been identified as potential Natura 2000 sites and are awaiting designation by the European Union. The duration of the project means that over 1200 students have been able to experience a summer of challenging ecological research, environmental education and direct conservation action, with many moving on to careers in these sectors. The student group has always had an international feel with students from across the world partaking. In recent years, growing numbers of Cypriot students studying veterinary and life sciences have been working as part of the project which augments the effectiveness

of the project and the cultural experience for all involved.

A full list of publications can be found at <cyprusturtles.org> but a highlight has been the satellite tracking studies over the years that have told us so much we didn't know about the life histories of both green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles. We have described their foraging locations - mostly along the north African coast, their over-wintering behaviour - moving offshore to deeper waters in the colder months where they do little but breathe – indeed we recorded the longest dive of an air breathing vertebrate – a loggerhead turtle whose dive lasted 10.5 hours and made it into the *Guinness Book of Records*! A second highlight has been that two of our PhD students have married Cypriot scientists and they are now living in Cyprus with their families and all working on ecological/environmental issues with NGOs or Universities.

Funding has always been a challenge, given the political sensitivities of working in the north of Cyprus, yet small pots of money from numerous funding bodies and hundreds of self-funded student volunteers who have worked day and night over the years have enabled the project to continue annually for more than two decades. We thank them all for their support.

Sadly, Ian Bell and Sally Solomon are no longer with us but the legacy of their generous mentorship and support continues.

Ecuador

A one-off expedition to northeast Ecuador took place in 1997, working on bird populations in degraded forest, and on begonias. However, a later series of University of Glasgow expeditions to Ecuador came about due to one of those happy coincidences that happen only very occasionally. Glasgow Zoology graduate Nan Swannie (a member of the Trinidad expedition in 1993) visited Ecuador on holiday and sampled some ecotourist experiences. By chance, wandering along the road in the Amazonian oil town of Coca she met a tour guide called Darwin Garcia and took his tour up the Rio Payamino to the community of San José de Payamino. Not long after she returned home, Nan visited Glasgow to give a talk on her experiences in Ecuador to the student Zoological Society. At the end of her presentation she mentioned that Darwin was keen to have scientific research conducted in the Payamino area. SW was in the audience and already a veteran of multiple student expeditions to Trinidad. He chatted to Nan over the usual post-lecture cheese and wine and, despite already having committed to a Trinidad expedition, agreed to propose an Ecuador expedition for the following summer, 2000.

The Ecuador Expedition proposal went down well with students in Exploration Society and after interviewing over 40 applicants a group was selected. The first Ecuador expedition was comprised of two research groups, a bird group led by Stewart White and an insect group led by GH from the Hunterian Museum and Graham Rotheray from the National Museums of Scotland. Both groups spent an initial period of three weeks at the private cloudforest reserve of Otonga in the Andes south of Quito. After this initial period of research the bird group travelled on to Amazonia and met up with Darwin and his brother Edwin to travel to Payamino. The first year saw many teething problems, inevitable when taking a group of students to a country for the first time and particularly when only two of the group had very basic Spanish and no knowledge of kichwa. The expedition was enough of a success, however, to encourage Stewart to arrange with Darwin and Giovanni Onore the owner of Otonga to make regular future visits.

At the time of writing there have been 12 University of Glasgow Ecuador expeditions, with the focus of the visits having gradually moved towards concentrating on Payamino. Well over 100 Glasgow undergraduate and postgraduate students have visited Ecuador on expedition, conducting research on leafcutter ants, butterflies, dragon and damselflies, fish, frogs and mammals. The bird research has continued to be the main project with the species list for Payamino now standing at 340 species and with several thousand individually marked birds flying around the rainforest carrying Swedish aluminium bands marked 'University of Glasgow', plus a few marked 'University of Dundee', but's that's another story!

As well as expeditions, an undergraduate field course, part of the final year Tropical Rainforest Ecology option has been running for the last 11 years. This gives the students the chance to study the rainforest ecosystem first hand and conduct short group research projects. The students selected have to pay a personal contribution but the field course is heavily subsidised by the University – evidence that the value of field teaching in such a biodiverse environment is appreciated.

The expeditions and field courses have given the students involved a unique experience and several who visited as 'ordinary' expedition members later returned as expedition leaders and in two cases as members of staff on University field courses in Payamino. Several of the students have gone on to post-graduate study and all would say that the Ecuador Expedition or field course was the most memorable part of their time at University. Along with the University of Manchester and Universidad Estatal Amazonico in Puyo we have been able to found a permanent research station at Timburi Cocha on the bank of the Rio Payamino (Fig.6). This

now welcomes researchers from Ecuador, North America and Europe and has seen the publication of several papers in peer-reviewed journals (e.g. Muir & Muir, 2011; White & Patino, 2017), with more in preparation. From entomological work during two of the Otonga cloud forest expeditions a number of hoverflies (Syrphidae) were reared from bromeliads and decaying plant material of two new species, *Copestylum ontongaensis* and *C. tapiai* (Rotheray *et al.*, 2007). All this was the result of a chance meeting in the dusty streets of Coca.

Fig. 6. Glasgow students and local people interacting at the Rio Payamino community, Ecuador (photo credit: Stewart White).

EDUCATION AND OUTREACH

Expeditions are educational in many ways: the participants learn a lot about the places they visit, develop new skills and learn about their own capabilities, as discussed by Harper *et al.* (2017). The results presented in the many publications derived from expeditions provide information on the places visited. However, expeditions have additional educational roles. In most cases, they work in collaboration with local organisations, sometimes government agencies, more often NGOs, as outlined in the earlier case histories. These collaborations provide many opportunities for two-way learning. In addition, many expeditions have built into their aims explicit educational activities. In the marine turtle focused expeditions run in both North Cyprus and at the RAF base at Akrotiri in the south, educating beach visitors about the turtles, threats to them and how to avoid causing harm have been constant activities. For several years, the Trinidad expeditions were involved in a British Council sponsored link between Glasgow and Trinidad schools; this involved working in Glasgow schools, carrying out educational activities related to the people, culture, environment and biodiversity of Trinidad; and in Trinidad schools, briefing students on Scotland, but also helping them to learn about their own biodiversity, based on our expedition findings; sadly, local biodiversity is poorly covered in the Trinidad school system, and the field trips the expeditions arranged for school groups were very popular. The Islay expeditions work closely with the Islay Natural History Trust and, through school visits, help children to learn about their local wildlife. Many other examples could be given; for more information, read the expedition reports in the GUExSoc archive.

DISCUSSION

It is clear from the account provided here that University of Glasgow expeditions have generated a vast amount of natural history information, both in Scotland and abroad, and that the size and scope of the expedition enterprise has grown hugely since the 1930s. It is also clear from this account and the research by Harper *et al.* (2017) that the expedition experience has been of great benefit to young people starting their careers in science. To finish this historical review, we ask some questions on sustainability and future aims. The loss of Carnegie funding has been very damaging to expeditions organised by Scottish Universities, and we hope that in time, the Trust will re-consider and develop a new scheme. Despite the demonstrable value of expeditions, the University of Glasgow itself does not have a clearly ear-marked method for funding them. We hope that this can be resolved in the near future. The Blodwen Lloyd Binns Bequest has been a valuable and reliable source of grants, but it does not possess the resources to be a major funder. As for the student population, the large number who attend the annual proposals meeting, where the next summer's expeditions are outlined, and students are invited to apply for places, shows no signs of diminishing enthusiasm. Students recognise the value of an opportunity to carry out real research which they have helped plan themselves, and which is carried out in a location far from their previous experience. However, although the students raise some of the funds through their own activities and personal contributions, the ever-rising costs of expeditions indicate the need for reliable external funding. As we have shown, Glasgow expeditions have been to locations both in Scotland and abroad. Both have generated valuable results and experiences, and we hope that they can continue into the future. Although Scottish based expeditions are less expensive and easier to organise, Scotland has a long history of engagement with other countries, and it is still the case that in many countries, the experiences, skills and interests of Scottish researchers and students can make valuable contributions to the expansion of knowledge.

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Seasonal trends in the temporal plasticity of breeding in blue tits and great tits in the Loch Lomond area

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ABSTRACT
Birds commonly increase their fitness by synchronising the emergence of their chicks with the peak in resource abundance in the environment. Climate change is driving earlier laying in many bird species, but within one season individuals may subsequently show additional plasticity. Presumably, birds benefit from being able to adjust the timing of their breeding activities according to environmental conditions. This plasticity in the timing of breeding is illustrated in blue tits (*Cyanistes caeruleus*) and great tits (*Parus major*) in the Loch Lomond area, Scotland. Birds use several mechanisms to fine-tune timing of breeding once laying has commenced. These include delays in clutch completion (laying gaps), modulating clutch size, and extending incubation periods beyond population average. We found a seasonal trend in these three mechanisms, with early breeding birds displaying larger laying gaps and extended incubation, and laying larger clutches, compared to later birds. Overall, we found increasing synchronicity with each breeding event across the population. No significant effects of delays in clutch completion and extended incubation period were found on hatching success or nestling weight. Whether the plasticity in the breeding process of tits arises due to a constraint (e.g. energy or nutrients), or a cue received from the environment is uncertain, but we need to improve our understanding of this plasticity in order to better predict the potential effects of climate change on breeding birds.

INTRODUCTION
The timing of breeding in birds is crucial, as they must synchronise the time of resource abundance in the environment with the peak energy demands of the chicks (Drent & Daan, 1980; Van Noordwijk *et al.*, 1995). Although breeding too early may be disadvantageous due to unpredictable environmental conditions, birds breeding earlier in the season are often more successful than those breeding later (Perrins & McCleery, 1989). Clutch size tends to decrease as the season advances, as birds' breeding output has possibly evolved to match the seasonal decline in favourable environmental conditions (e.g. food availability; Perrins & McCleery, 1989). However, reduced clutch size is also a means for birds to adjust the time of hatching of their clutch, because many species only fully incubate once a clutch is complete. Thus, smaller clutches advance hatching. Other breeding activities can also be adjusted with effects on hatching time, including laying patterns and intensity of incubation.

The peak of resources in the environment fluctuates on different time-scales. On an inter-annual time-scale, an increase in early spring temperatures caused by climate change is driving many changes in the seasonal emergence of resources. For instance, Polgar & Primack (2011) report a progressive shift to earlier timing of bud burst, resulting in earlier emergence of caterpillars, which may favour a hasty start to breeding in birds. Evidence for the advancement of breeding dates has been found in pied flycatcher (*Ficedula hypoleuca*; Both &Visser, 2001), spotted flycatcher (*Muscicapa striata*; Both *et al.*, 2004) and tree swallows (*Tachycineta bicolor;* Dunn & Winkler, 1999), amongst others. On a short time-scale, the progress of tree phenology can vary within one season; for instance, a cold-spell may delay leafing, consequently affecting the time of caterpillar emergence, an important resource for many breeding birds (Van Asch *et al.*, 2013).

Blue tits *(Cyanistes caeruleus)* and great tits *(Parus major)* are small passerine birds native to mixed woodland areas. These species have large clutches (10-12 eggs for blue tits, 6-11 eggs for great tits) which hatch altricial young, requiring food provisioning during approximately three weeks (Snow *et al.,* 1997). The total length of the breeding period is approximately 40 days (Snow *et al.,* 1997). Synchronising the emergence of chicks with environmental resources is complex, because there is a long time-span (at least ca. three weeks) between the laying of the first egg and hatching. This time-span, however, also offers opportunities for modulating breeding behaviour in response to environmental constraints or cues. Blue tits and great tits typically lay one egg per day (Perrins, 1979), and the incubation period lasts 13 days on

average (Snow *et al.*, 1997). However, variation in the timing of these two periods has been reported, in the form of "laying gaps" (Nilsson & Svensson, 1993) and an extended incubation period (White & Kinney, 1974; Haftorn, 1981).

Laying gaps, defined as interruptions in laying occurring between the laying of the first egg and the completion of the clutch, are reported by Dhondt *et al.* (1983), in a population of breeding blue tits and great tits. In this paper, the frequency of laying interruptions in blue tits was correlated to the preceding year's winter temperatures, whereas interruptions in great tit laying were correlated to the feeding conditions during the laying period. Nilsson & Svensson (1993) observed gaps in laying in 27% of great tit clutches in a population in southern Sweden. Provisioning extra food to females before laying had a significant negative effect on the frequency of laying gaps, with only 8.3% of the provisioned females interrupting their laying (compared to the 27% in control birds).

An extended incubation period, defined as an incubation period longer than average for the population, could be due to two main reasons: a later start to incubation, or lower incubation temperature for example due to interruptions in incubation. Reduced incubation temperature may allow birds to further delay hatching date, but could also have significant costs associated. For instance, Nord & Nilsson (2011) report that reduced incubation temperatures result in lower hatching success and smaller tarsus length in blue tits. Modulation in incubation period has been reported in wild birds in inter-annual comparisons of populations of marsh tits *(Poecile palustris;* Wesołowski, 2000), and great tits (Cresswell & McCleery, 2003).

These modulations in breeding behaviour could be a physiological response resulting from a constraint imposed by environmental conditions, for instance a bird being too energy-constrained to lay a second egg immediately after the first, or to keep eggs at optimal incubation temperature. However, delays in breeding could also be a mechanism to maintain synchronisation after receiving certain environmental cues, as argued by Cresswell & McCleery (2003). In this scenario, the bird is able to lay a second egg but nonetheless delays laying in order to extend the breeding period to match the food peak in the environment. Potential cues in the environment that could modulate breeding in birds are temperature, food-availability, or tree leafing (Visser *et al.*, 2004). In both the "cue" and the "constraint" scenario, delays in breeding could result in fitness consequences in terms of breeding success, if, for instance, temperature during incubation has decreased below that necessary for embryonic development (Haftorn, 1981; Olson *et al.*, 2006). Our present study arose due to observations made during the breeding season of 2017 (April-June 2017). The breeding season started earlier this year than previously recorded in our study system (see below), prompting the question of whether birds would maintain a regular pace of breeding, or would extend the breeding process after the unusually early start. We aim to illustrate the delays observed in the breeding process of blue tits and great tits, and to asses if there are any resulting fitness correlates. Our report is the first mention of breeding delays in Scotland; it also demonstrates that a trend in the length of the laying and incubation periods can be observed within a single breeding season.

Our hypotheses were two-fold; our first hypothesis was that due to the early start in laying, we would encounter laying gaps and extended incubation amongst the population. Specifically, we predict that lags in laying and incubation will be observed more frequently amongst early breeders than later in the season. Our second hypothesis was that, in agreement with previous studies, the clutch size of tits would decrease through the season, as a result of selection to match the resource fluctuation, or due to an energy constraint. Finally, we predict that interruptions in laying and extended incubation will have consequences for the breeding success of birds.

METHODS

The nests referred to in this report are all part of the Glasgow Gradient, an experimental set-up with a selection of sites across a gradient of urbanisation (Pollock *et al.*, 2017 and Capilla-Lasheras *et al.*, 2017 for details). The sites included in this report are those at the rural end of the gradient: the area of woodland surrounding the Scottish Centre for Ecology and the Natural Environment (SCENE; 56°07'34.4"N, 4°37'04.6"W), the area of woodland adjacent to Sallochy bay (56°07'34.7"N, 4°36'20.9"W), and the woodland surrounding Cashel farm (56°6'45.0"N, 4°34'32.9"W), all three on the banks of Loch Lomond. These three sites contain a total of 412 nestboxes (Woodcrete, Schwegler, Germany; dimension = 260H × 170W × 180D cm; hole diameter = 32 mm), commonly occupied by blue tits and great tits.

Starting on 9 March 2017, weekly checks were carried out on all the nest boxes, monitoring and recording nest building and egg-laying. Once egg-laying was completed, the earliest possible hatch date was calculated, by estimating the date of the final egg (assuming one egg/day), and adding 12 days of incubation (including day of clutch completion). Nestboxes were checked on the estimated hatch date and every other day after that if the eggs were still intact. Once hatching began (Fig. 1), the date was recorded along with the number of hatchlings. Hatching success was calculated by dividing the number of eggs by the number of hatchlings. For a subset of boxes (n=51 in SCENE, n=4 in Sallochy, n=34 in Cashel), nestlings were weighed and ringed on day 8 after hatching. After the

young had fledged, the nest boxes were cleared out and any dead chicks found were removed and recorded. The number of dead chicks found in the nest was used to calculate fledging success (fledglings/hatchlings).

Fig. 1. Blue tit chicks on the day of hatching, from the woodlands around SCENE. Photograph by Crinan Jarrett.

An extended data set from the Glasgow Gradient was used to compare timing of breeding in 2014-2017. These data had been collected following the same protocol of nestbox checks mentioned above. From this extended data set, a mean start of laying and a mean start of hatching was extracted, along with the data of the first egg and the first hatchling in the population (defined below). Data on the bud burst of trees in the forests of SCENE and Cashel were collected on a weekly basis by observing the canopy of each nestbox-carrying tree through binoculars, and scoring bud burst from 0 to 5, using the categories detailed by Derory *et al.* (2006). Data for the daily mean temperature at Gartocharn Portnellan Farm (56°2'55.9"N, 4°34'0.2"W), 9.4 km from SCENE, were obtained from the Met Office Library & Archive.

The following arguments were used during the analysis:

At population level

a) Date of first egg in population: estimated based on weekly visits to nests, assuming daily laying. Maximum error = 6 days.
b) Mean start of laying: calculated from data from SCENE, Cashel and Sallochy.
c) Date of first hatchling in population: estimated from visits to nestboxes on the estimated date of hatching, and then every two days after that. Maximum error = 1 day.
d) Mean start of hatching: calculated from data from SCENE, Cashel and Sallochy.

At individual nestbox level

e) Date of first egg: estimated based on weekly visits to the nests, assuming daily laying. Maximum error = 6 days.
f) Date of laying completion: estimated based on the number of eggs in the complete clutch and the information from the weekly visits to the nests. Maximum error = 6 days.
g) Delay in laying completion or "laying gaps": defined as any days beyond those necessary to lay a complete clutch assuming one egg per day (i.e. for a clutch of 7 eggs, 7 days would be the estimated laying period, whereas 9 days would imply 2 days of delay).
h) Delay in hatching or "extended incubation": defined as any days beyond the 13 day incubation period, the average for blue tits and great tits (Snow *et al.*, 1997), assuming incubation starts with the last egg. A negative figure for delay in incubation implies an incubation period of less than 13 days, a start of incubation prior to clutch completion, or estimation error based on the above.

All bird sampling was conducted following the directions and legislations of the Scottish Natural Heritage (52463 to BH) and the British Trust for Ornithology (Scientific C licence to BH). Statistical analyses were performed in R (version 3.3.3) using the platform RStudio (version 1.0.136). General linear models (GLMs) were constructed using the package *stats* (R Core Team, 2017). Models were selected by backward elimination of variables from full models, where the starting point was a model containing all variables deemed biologically plausible (Table 1), and potential interactions between them. The best-fit model was selected based on its performance being significantly better ($p<0.05$) when compared to the model resulting from dropping an additional variable (chosen based on lowest Akaike's Information Criterion). This selection was done using Likelihood Ratio Tests (LRTs), with the package *lmtest* (Zeileis & Hothorn, 2002). Residuals of the best-fitting model were plotted and visually assessed to ensure that parametric assumptions were met. The reported LRT output is that obtained by comparing the best-fit model with the model resulting from dropping an additional variable in the step-by-step deletion process. We used a binomial distribution for modelling hatching success. The package *moments* (Komsta & Novomestky, 2015) was used to calculate kurtosis and skewness in the long-term Glasgow Gradient data set. The package *ggplot2* (Wickham, 2009) was used to create the plots.

RESULTS

The date of the first egg in the population and the mean start of laying were earlier in 2017 than the three previous years (2014-2016, Table 2). The date of first hatchling in the population and the mean start of hatching were also earlier in 2017 than in previous years. For the 2017 breeding season, clutches laid earlier in the season tended to have more laying gaps compared to clutches laid later, for both blue tits (Fig. 2e) and great tits (Fig. 2f).

Response variable	Explanatory variables Full model	Best-fit model
Delay in laying completion	Date of first egg Species Clutch size Site Site*Date of first egg Species*Date of first egg Temperature	Date of first egg Clutch size
Delay in hatching	Date of laying completion Clutch size Species Site Site*Date of laying completion	Date of laying completion Clutch size Site*Date of laying completion
Clutch size (Blue tits)	Date of laying completion Site	Date of laying completion Site
Clutch size (Great tits)	Date of laying completion Site	
Hatching success	Delay in laying completion Clutch size Site Species Date of laying completion	
Nestling weight	Delay in laying completion Delay in hatching Clutch size Site Date Species	Clutch size Site Species
Nestling weight range	Delay in laying completion Delay in hatching Clutch size Site Date Species	Species

Table 1. Response variable and explanatory variables for all models used in analysis. An asterisk (*) between two terms indicates an interaction. The full model contains all variables deemed biologically plausible, and the best-fit models contain all variables remaining after backwards selection.

	Date of first egg in population	Mean start of laying	Date of first hatchling in population	Mean start of hatching	Mean temperature of previous winter
2017	12-April	25-April	8-May	17-May	5.0°C
2016	20-April	1-May	16-May	24-May	4.5°C
2015	21-April	5-May	18-May	28-May	3.5°C
2014*	24-April*	1-May*	15-May*	20-May*	4.8°C

Table 2. The timing of different breeding events in blue tits and great tits in the years 2014-2017: for years 2015-2017, data were extracted from all the boxes in SCENE, Cashel and Sallochy. For 2014 (*), only the data from Cashel were used. Mean temperature (°C) of the winter (Dec, Jan and Feb) previous to breeding season is for W. Scotland.

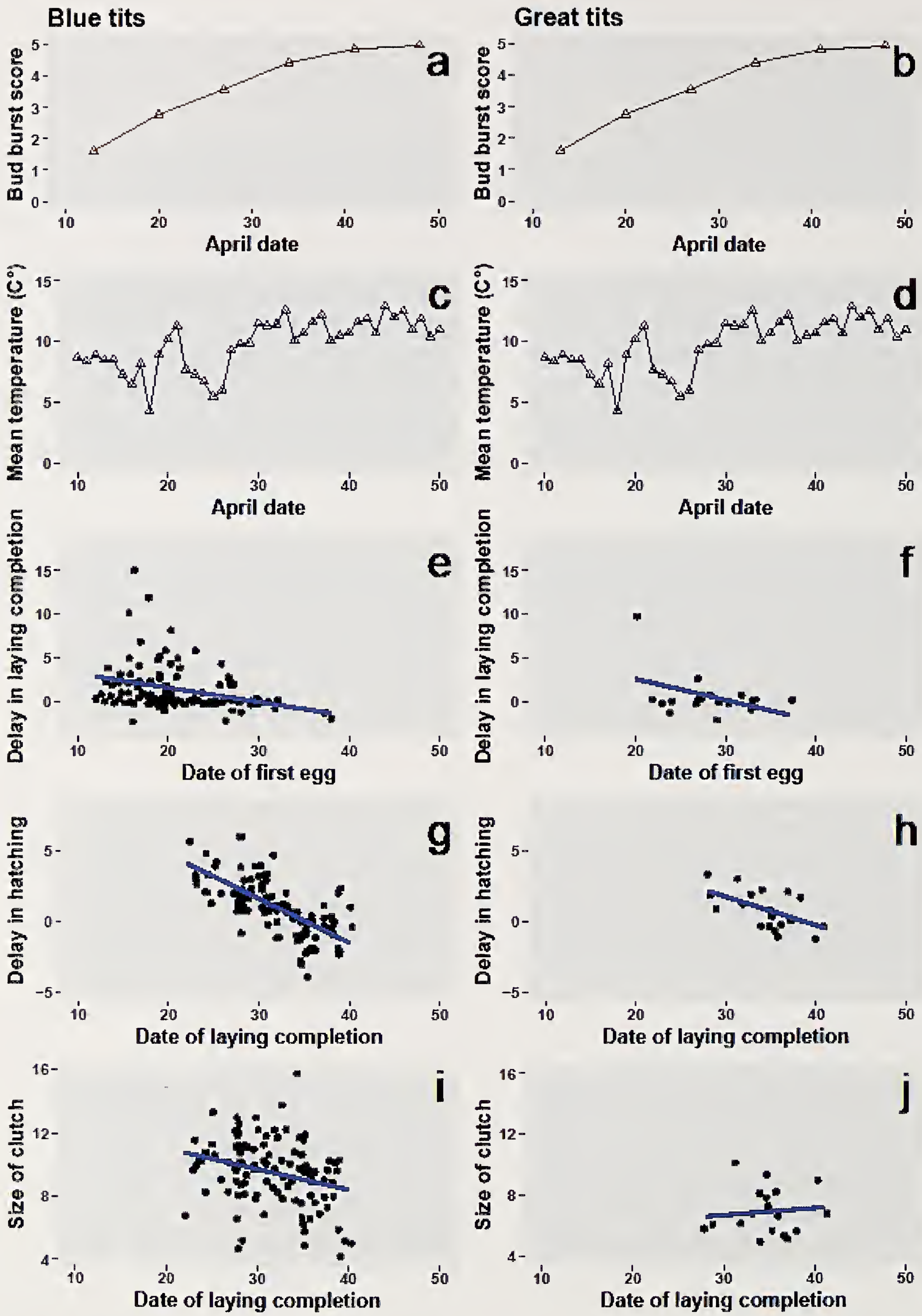

Fig. 2. Phenology: mean bud burst score for SCENE and Cashel, between 10 April and 20 May 2017 (a and b). Average daily temperature between 10 April and 20 May 2017 (c and d). The delay in laying completion (number of extra days taken to complete clutch beyond 1 egg/day) plotted against the date of first egg for blue tits (e) and great tits (f) in Cashel and SCENE. Clutch size (number of eggs) of blue tits (g) and great tits (h) plotted against the date of laying completion. The delay in hatching (number of days exceeding the expected 13 day period) plotted against the date of laying completion for blue tits (i) and great tits (j). The dates are expressed using the April Date system, where number 1 = 1 April 2017.

The later clutches, in some cases, shortened the estimated laying period duration expected from daily laying, by maximally three days. The model best explaining the *delay in laying completion* (LRT: $x^2(1)=39.66$, $p<0.0001$), contained the explanatory variables *date of first egg* (slope±SE =-0.22±0.02, $p<0.0001$) and clutch size (-0.52±0.1, $p<0.0001$; Table 1). The variables site, species, temperature at date of first egg and the interaction between species and *date of first egg* did not explain significant amounts of variation ($p>0.05$) and were dropped from the final model. There was a correlation found between temperature and date (correlation coefficient = 0.62), with temperature increasing as the season advances.

The initial model to explain variation in clutch size in blue tits and great tits contained as explanatory variables *date of laying completion*, site and species. However, there was a significant effect of the interaction between species and *date of laying completion* ($p=0.001$) on clutch size, and therefore further analysis was done using a separate model for each species. For blue tits, the best-fit model (LRT: $x^2(1)=9.5$, $p=0.002$) contained the variables *date of laying completion* (-0.13±0.04, $p=0.002$) and site (-1±0.37, $p=0.008$ for SCENE; Table 1). Average clutch size per nest was larger for the birds laying early in the season, and smaller for those laying later (from ca. 11 to 7 eggs; Fig. 2g). The *date of laying completion* did not have a significant effect on the clutch size of great tits ($p>0.05$, Fig. 2h).

The *delay in hatching* decreased significantly with date in both blue tits (Fig. 2i) and great tits (Fig. 2j). Birds starting incubation earlier tended to have a longer incubation period than those starting later in the season. The model best explaining variation in *delay in hatching* (LRT: $x^2(2)=95.39$, $p<0.0001$) contained the explanatory variables *date of laying completion* (-0.27±0.02, $p<0.0001$), clutch size (-0.22±0.05, $p=0.0001$), site (-2.8±1.3, $p=0.03$ for SCENE) and an interaction between site and the *date of laying completion* (0.08±0.03, $p=0.03$; Table 1). Species had no significant effect on *delay in hatching* ($p>0.05$), nor did the interaction term between species and *date of laying completion*.

Overall, the synchrony within the population in the timing of breeding activities increased through the season (Fig. 3). This increase in synchrony can be seen in the decreasing standard deviation, range and coefficient of variation of the data (Table 3). The coefficient of variation drops from 32.2 for date of first egg, to 10.2 for date of hatching. Kurtosis is higher in the two later events, indicating curves with less weight on the tails (Sokal & Rohlf, 1981). All three curves are positively skewed, indicating a higher frequency of events early in the range.

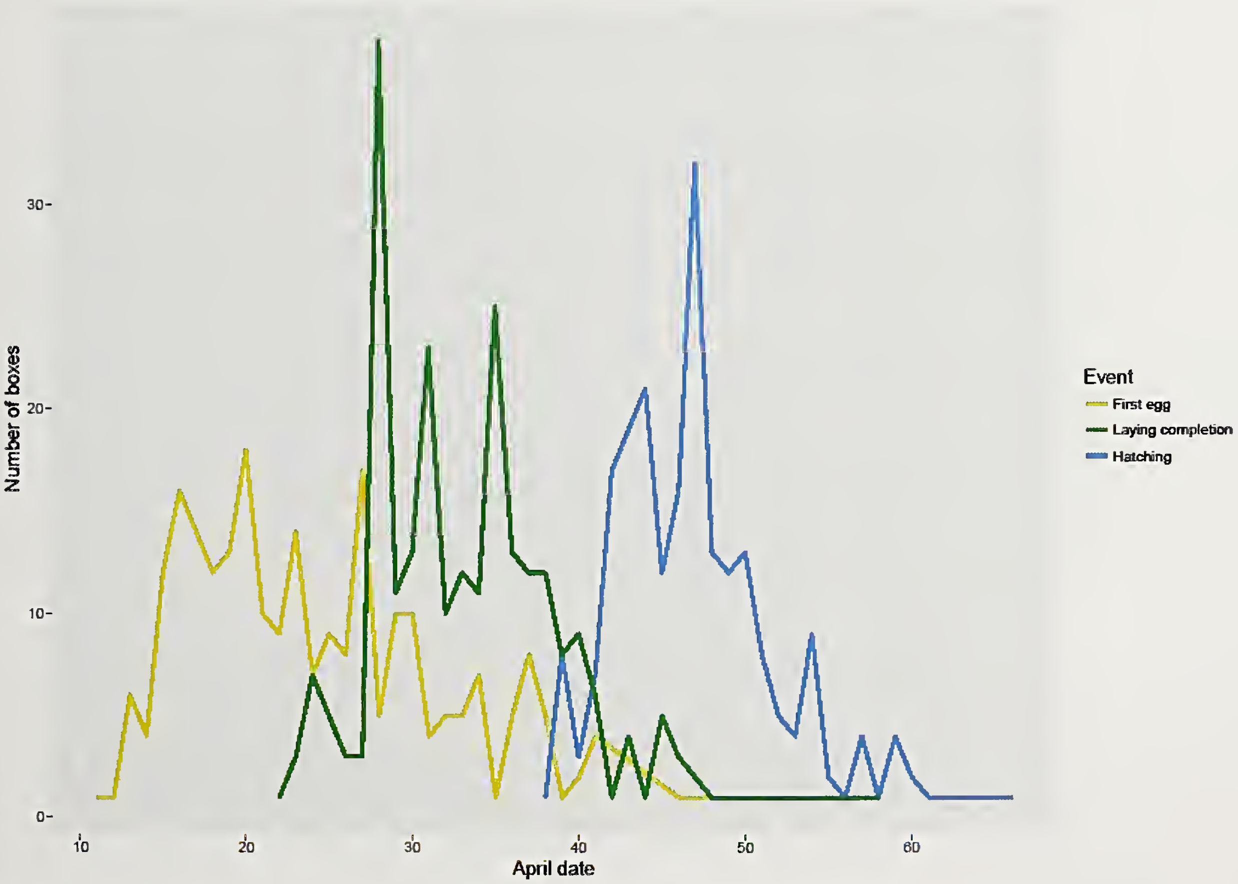

Fig. 3. Frequency plot illustrating the number of boxes on each day for the three main breeding events (date of 1st egg, date of laying completion and date of hatching).

Event	Mean±sd	Range	CV	Kurtosis	Skewness
1st egg	24.4±7.8	43 (11-54)	32.2	3.2	0.75
Laying completion	33.5±5.9	36 (22-58)	17.8	3.9	0.78
Hatching	46.9±4.8	28 (38-66)	10.2	3.9	0.84

Table 3. For three breeding events (date of first egg, date of laying completion and date of hatching): mean and standard deviation (sd), range, coefficient of variation (CV), kurtosis and skewness of data.

Hatching success of the birds was not significantly affected by laying gaps, nor by the variables site, clutch size, species, or date of laying completion ($p>0.05$). After dropping these variables one by one, the null model proved to be best fit (LRT: $x^2(1)=1.8$, $p=0.17$; Table 1). The same results were obtained using a Gaussian and a binomial distribution. The best-fit model to explain nestling weight at day 8 (LRT: $x^2(1)=7.9$, $p=0.004$) contained the explanatory variables species (5.7±0.17, $p<0.0001$ for great tit), clutch size (-0.08±0.02, $p=0.005$) and site (-1.42±0.35, $p<0.0001$ for Sallochy; Table 1). The delay in laying completion and the delay in hatching did not have a significant effect on the weight of the chicks on day 8 ($p>0.05$), and were dropped from the final model. The best-fit model to explain within-nest variation in chicks, calculated as the standard deviation of the weights of all chicks from one nest, contained only species as an explanatory variable (LRT: $x^2(1)=11.9$, $p=0.0005$; effect of species 0.3±0.08, $p=0.0007$ for great tit; Table 1). Clutch size, site, date, delay in laying completion and delay in hatching were non-significant ($p>0.05$) and were dropped from final model.

DISCUSSION

The breeding season of 2017 started earlier than in the three previous years, which was reflected both in the start of laying, and in the date of hatching. The mean temperature of the 2016-17 winter was higher than the three previous years, indicating a possible correlation between milder winters and earlier spring breeding. Under a climate change scenario, there is contrasting evidence showing that birds either sufficiently change their breeding timing to match environmental resources (McCleery & Perrins, 1998) or do so insufficiently, resulting in a mismatch between the timing of breeding and maximum resources (Visser *et al.*, 1998). The time-lapse between the start of laying and hatching adds complexity to the synchronisation of breeding in birds.

The main predictor for laying gaps was the date. Specifically, laying gaps decreased throughout the 2017 breeding season, meaning that late-breeding birds showed little delays, whereas birds breeding earlier tended to lay at a slower rate. Temperature was found to be a poorer predictor than date for explaining delay in laying completion, and was consequently dropped from the final model. This finding is not fully consistent with most of the literature on laying gaps, which emphasises a correlation between temperature and the frequency of gaps (Dhondt *et al.*, 1983; Nilsson & Svensson, 1993; Cresswell & McCleery, 2003). An experimental set-up by Yom-Tov & Wright (1993), where boxes were heated artificially, resulted in a lower frequency of laying gaps in heated boxes. To our knowledge, the correlation between date and frequency of laying gaps has been documented only by Lessells *et al.* (2002) in a population of great tits. However, the variables temperature and date are difficult to separate. Indeed, there was a relatively strong correlation between these variables in our data-set. Thus, our results on a minor role of temperature as a driving factor for delays in laying are tentative. Various factors should be taken into account: for example, the weather data included are only a mean temperature, and this may not be the driving factor for birds' breeding pattern, and it is unsure whether the determining temperature for laying gaps is that of the first day of laying. These queries would benefit from high resolution weather information and a longer time-series of data on birds' breeding activity (e.g. Cresswell & McCleery, 2003 and Visser *et al., 1998*).

Delay in laying completion was also affected by clutch size, with less delay occurring in boxes with larger clutches. Larger clutches will naturally take a longer time to lay, and thus (all else being equal) hatching is pushed back with every added egg. Laying a small clutch but at a slow rate (with laying gaps) could be a "budget" version of this same behaviour, the outcome being the delay in hatching date. This mechanism could be a result of a constraint on the ability of some birds to produce eggs on a daily basis, and could entail fitness consequences. However, clutch size and laying delays decreased throughout the season. Therefore, the longer delay in larger clutches could simply be re-iteration of the shared trend to decrease through the season.

The modulation in clutch size by birds according to laying date has long been discussed in the literature (Lack, 1968; Perrins & McCleery, 1989), and is seen as an adaptive behaviour to better match environmental resources. In this report, clutch size was found to decrease throughout the season in blue tits, as expected. There was also a significant effect of site on clutch size, with SCENE having smaller clutches than Cashel. This phenomenon has been observed in previous years in the Glasgow Gradient (Helm *et al.*, unpublished data), and may be a result

of a more mature and resource-rich woodland in Cashel. The lack of a correlation between clutch size and date of the first egg in great tits may be a result of a smaller sample size (n=41 breeding pairs for great tits, n=159 for blue tits).

The delay in hatching followed a seasonal pattern similar to the delay in laying completion, decreasing progressively as the season advanced. Thus, birds breeding earlier had an extended incubation period compared to birds breeding later, matching our initial predictions. The decrease in incubation period with advancing spring dates has been documented previously in marsh tits (Smith, 1993; Wesołowski, 2000), both within seasons and between seasons. Cresswell & McCleery (2003) find no seasonal trend in total incubation period in great tits in the mixed deciduous woodland of Wytham Woods. However, they identified the extent of incubation on the day of clutch completion (percentage of time spent on nest) as one defining factor for incubation period: the more time a bird spent incubating on that specific day, the shorter the total incubation period was. Consistent with these results, Wang & Beissinger (2011) review the concept of "partial incubation", defined as a reduced amount of time during egg laying or full incubation that parents sit on and warm their eggs. Partial incubation is found to be present in multiple species of bird including great tits (Wang & Beissinger, 2011), and could be one potential explanation for a modulation in the time-span between laying initiation and hatching.

Other variables explaining delay in hatching were clutch size, site, and the interaction between site and date of laying completion. Larger clutches tended to have less delay in hatching, matching the results for delay in laying completion. An extended incubation period could be an alternative behaviour adopted by birds with small clutches, resulting in a later hatching date possibly beneficial to adjust to environmental fluctuations. Also, as clutch size decreases with the season, the effect of clutch size on delay in hatching could simply be a re-iteration of the temporal trend. Site has a significant effect on the delay in hatching, with SCENE having less delay than Cashel. As the interaction between site and date of laying completion is significant, we can assume that the breeding process at SCENE is later, resulting in less delay.

The fitness consequences of delaying laying completion and delaying hatching are hard to predict. On the one hand, if these mechanisms allow greater synchronisation with environmental resources, one would expect breeding success to be higher in birds who display plasticity in the timing of breeding. Additionally, if delaying allows parents to better budget their energy reserves, this may be beneficial for parent fitness as well (Wang & Beissinger, 2011). On the other hand, it has been shown that egg viability decreases with time of exposure to ambient temperature (Beissinger *et al.*, 2005; Wang *et al.*, 2011), and that reduced temperature during incubation results in lower hatching success (Nord & Nilsson, 2011), indicating that delays in both laying and incubation could be detrimental to breeding success.

In this report neither the delay in laying completion nor the delay in hatching had clear consequences on breeding success. Birds who did delay the breeding process had neither higher nor lower hatching success. Nor did they produce smaller nestlings compared to birds who did not delay. One possible way to explain this is that the fitness correlates analysed were not the ones affected by delays in breeding. For instance, the main consequences of delaying could be seen in the body condition of the parents, which could be assessed in future studies (Wang & Beissinger, 2011). A second possible explanation is that the penalty for delaying birds was masked because of good environmental conditions. In this case, in a year with very poor environmental resources, the constrained birds could suffer direly for their delays.

In this study, *there* appears to be a general trend to greater synchronicity as the breeding season advances. The start of laying is a lot more variable compared to the hatching date of birds in the population. This trend supports the idea that the main event which requires synchronisation with environmental resources is hatching, rather than the initiation of the whole breeding process (Cresswell & McCleery, 2003). It is possible that a long-term trend to earlier warm springs due to climate change selects for birds to start breeding early, however it will be beneficial for birds to be able to "tailor" their behaviour once laying has started, to be able to cope with unexpected short-term conditions such as a cold spell.

In this study we document a clear temporal trend in the delay of laying completion, clutch size, and the delay in hatching, which adds evidence to the use of these three mechanisms to synchronise breeding within a population, presumably to match the peak in environmental resources. In a highly fluctuating environment, both within and between seasons, it is yet unclear whether the plasticity in breeding phenology of birds results from an environmental cue or from an imposed constraint. In our study we detected no fitness consequences of breeding delays. Although we cannot fully rule out these consequences, it may be that plasticity in breeding activities is sufficient to counteract environmental fluctuations. The timing of breeding in birds may indeed benefit from a degree of plasticity, but these benefits may be context dependent. We are entering unchartered territory, and a wider understanding of the range of responses available for birds to survive a changing climate is necessary.

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A review of the geographic distribution, status and conservation of Scotland's lampreys

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INTRODUCTION

Lampreys (Petromyzontiformes) are a diverse group of jawless fishes, comprising approximately 45 species distributed in both northern (41 species from one family, Petromyzontidae) and southern hemispheres (four species from two families, Geotriidae and Mordaciidae) (Renaud, 2011; Mateus et al., 2013; Tutman et al., 2017). Larval lampreys are filter-feeding life-stages commonly located in fluvial sediments (Hardisty, 2006). After several years of growth larvae undergo a radical metamorphosis and the distinctive adult lamprey phenotype is produced (Bird & Potter, 1979). Adult lampreys are broadly characterized as being parasitic (feeding on the blood and/or tissue of fishes) or nonparasitic (non-trophic). Nonparasitic species are often referred to as "brook lampreys". Three species of lamprey can be found in Scotland: sea lamprey (*Petromyzon marinus* Linnaeus 1758), European river lamprey (*Lampetra fluviatilis* Linnaeus 1758), and European brook lamprey (*L. planeri* Bloch 1784).

Recent investigations have revealed that in many ways European river and brook lampreys exemplify the lamprey "species problem": one is parasitic (*L. fluviatilis*) the other nonparasitic (*L. planeri*). However, they are found sympatrically across almost their entire range (Renaud, 2011); larvae are distinguishable only during the latter stages of metamorphosis (Bird & Potter, 1979); they frequently share spawning grounds (Huggins & Thompson, 1970; Lasne et al., 2011); can readily hybridize (Hume et al., 2013); and, where they co-exist, are not reciprocally monophyletic (Espanhol et al., 2007; Bracken et al., 2015). In addition, although *L. fluviatilis* is typically anadromous some populations feed exclusively in freshwater lakes (Berg, 1948; Adams et al., 2008; Inger et al., 2010) or for reduced periods of time in marine environments (Abou-Seedo & Potter, 1979; Hume, 2013). The lampreys of Loch Lomond in west-central Scotland are of particular scientific and conservation importance because of the presence of a lake-feeding *L. fluviatilis* population there (Hume, 2013). The species status of both these fishes is open to debate, but such a discussion is out-with the scope of this study. The distantly related sea lamprey also appears to be more ecologically variable than previously assumed. Some individuals of this typically anadromous species have been found to remain feeding parasitically in freshwater lakes in Ireland (F. Igoe, Irish Char Conservation Group, *pers. comm.*) and may represent the first stages in establishing a freshwater-resident population. There are substantial numbers of angler records of sea lamprey parasitizing brown trout (*Salmo trutta* L. 1758) and northern pike (*Esox lucius* L. 1758) in Loughs Derg, Conn, Cullin and Corrib (Rare Fish Reporter, http://www.ucd.ie/rarefishreporter/ accessed June 2017). Recently transformed sea lamprey are known to feed within rivers during their downstream migration to the sea (e.g., Silva et al., 2013), so feeding in lakes is not necessarily a complex transition for this species.

The ecological, behavioural and phenotypic variability of lamprey species has profound implications for their management in Scotland, the wider U.K., and elsewhere in Europe. Despite the difficulty in comprehending and assigning the taxonomic designation of "species" to organisms and the restrictions such assignations produce, these artificial constructs are a necessity if we wish to adequately protect our natural heritage from exploitation and/or extinction. Therefore, as a first step we must comprehend the full extent of lamprey biodiversity (phylogenetic, morphological, behavioural and phenotypic) and then seek ways to protect that diversity at both the species and sub-specific level where necessary. The aim of this study was to document the geographic extent of each of Scotland's three lamprey species using information derived from previously published sources. Given the difficulty in identifying larval lampreys to species level only credible adult sightings are presented to give a truer picture of each species' range. Metadata were derived from primary and grey literature, including Government and non-Government sources. Records ranged in date from 1883 to 2016. In addition, the conservation legislation protecting each species and the current status of Scottish populations is also outlined. Some notes on potential

future directions for lamprey conservation and their relevant ecology are also provided.

GEOGRAPHIC DISTRIBUTION OF ADULT LAMPREYS IN SCOTLAND

Sea lamprey are present in all seven hydrological regions of Scotland. However, the single record from Shetland (Landon Water, dated 1883) may represent a vagrant individual given the species' scarcity in the north (Table 1). Sea lamprey are known to travel extensive distances in the north Atlantic during the juvenile trophic phase, and specimens have been recovered hundreds of kilometers off the coasts of Europe (Lelek, 1973; Pereira et al., 2012). In total, 240 records of adult sea lamprey were identified from 39 river systems (Fig. 1). European river lamprey were recorded in 35 rivers across all regions of Scotland except Orkney and Shetland (Fig. 2). This species is most common in the South West (14 catchments) and Grampian (10 catchments) regions (Table 1). A similar number of records were located for European river (224) and sea lampreys. But only a single occurrence of the species was noted in the Western Isles hydrological region (Glenlussa Water on Kintyre, a mainland site). And surprisingly there are no records from any of the Scottish islands. European brook lamprey were recorded from 62 Scottish river catchments, indicating they are the most widespread species in the country (Table 1). In total, 444 records were obtained from all hydrological regions, again with the exception of Orkney and Shetland (Fig. 3). As with European river lamprey there is a strong regional trend in the distribution of adult records, with most occurrences in the Grampian and South West regions. However, species records were obtained from the Western Isles region (River Broadford on Skye; Laggan on Islay) and two rivers in the far north of Scotland's mainland (Hope and Wick), disjunct from the northern range of the species.

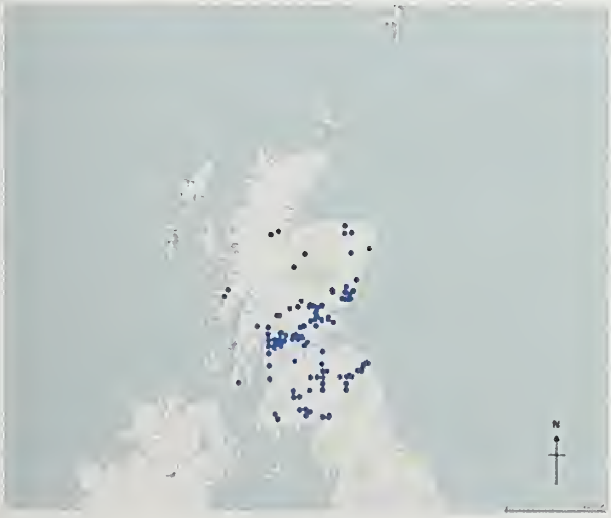

Fig. 1. Geographic distribution of *P. marinus* in Scotland. Only records of adults are indicated.

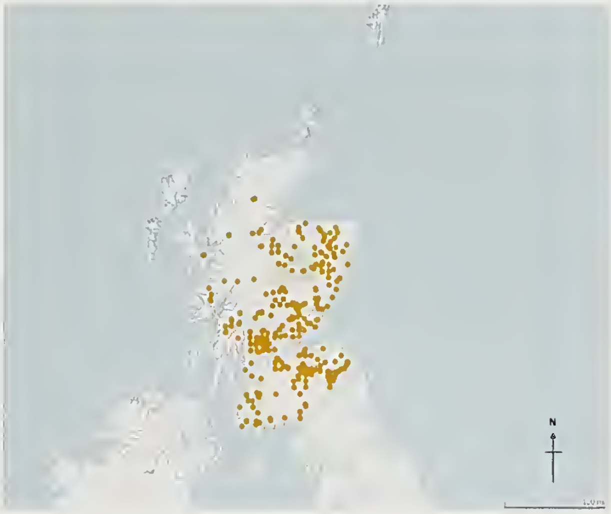

Fig. 2. Geographic distribution of *L. fluviatilis* in Scotland. Only records of adults are indicated.

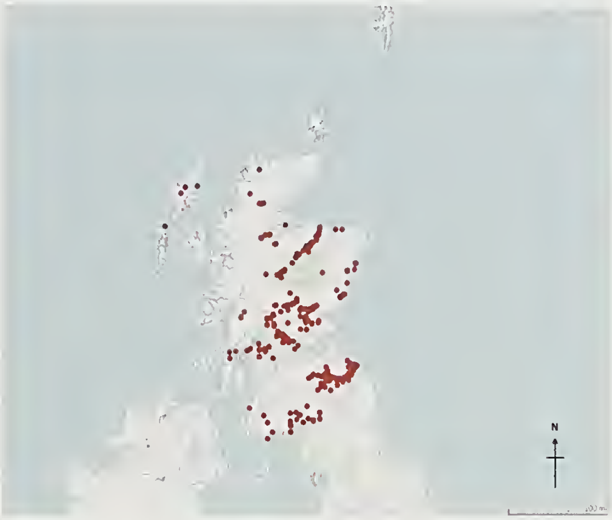

Fig. 3. Geographic distribution of *L. planeri* in Scotland. Only records of adults are indicated.

STATUS OF LAMPREY POPULATIONS IN SCOTLAND

All three lamprey species present in Scotland are categorized as being of 'Least Concern' (IUCN, 2015). For sea lamprey this designation is based on a large geographic range (eastern North America and western-northern Europe), many sub-populations with substantial population sizes, and a lack of major threats across their range. Scotland is located near the northern limit of the breeding range of sea lamprey (Maitland, 1980), possibly due to the intolerance of embryos to cool water temperatures (Langille & Hall, 1988). As such it has previously been suggested that the species may never have been common in Scottish rivers (Gardiner & Stewart, 1997). However, within the U.K. larval sea lamprey were found to occupy 305 1 x 1 km squares of surveyed habitat (National Biodiversity Network), and 120 of those (39%) were in Scotland (JNCC, 2013a). Unfortunately it is not possible to estimate population sizes based on such grid surveying methods, and despite larvae being widespread in

River System	P. marinus	L. fluviatilis	L. planeri
Allan		X	X
Amhainn Dubh	X		
Annan	X	X	X
	X		X
Ayr	X		X
Barvas			X
Bervie	X	X	X
Black Cart	X		X
Bladnoch	X		X
Broadford			X
Carron			X
Clyde	X	X	X
Connon	X	X	X
Craigmill			X
Cree	X	X	X
Creed	X		
Dee	X		X
Deveron	X	X	X
Devon		X	
Dighty			X
Don	X	X	X
Doon	X		
Eachaig	X		
Eam	X	X	X
Eden			X
Endrick	X	X	X
Esk	X	X	X
Eye			X
Findhorn			X
Fleet			X
Forth	X	X	X
Garnock	X		X
Girvan	X		X
Glass		X	
Glenlussa		X	
Hope	X		X
Inver	X		
Irvine		X	X
Kelvin	X	X	X
Kirtle		X	X
Laggan			X
Landon	X		
Leith		X	X
Leven	X	X	X
Lochar			X
Lochy	X		X
Lossie			X
Luce		X	X
Lunan		X	X
Monikie			X
Morar			X
Morsgail	X		
Nairn			X
Ness			X
Newhall Burn			X
Nith	X	X	X
North Esk	X	X	X
Oykel	X		
Peffery		X	X
Piltanton		X	X

Shiel		X	X
Shira			X
South Esk	X	X	X
Spey	X	X	X
Stinchar	X	X	X
Tay	X	X	X
Teith	X		X
Tweed	X	X	X
Tyne			X
Urr	X	X	X
White Cart		X	X
Wick			X
Ythan		X	X

Table 1. Rivers in Scotland where adult lampreys have been recorded. Rows in grey indicate river systems that harbour all three species.

Scotland sea lamprey population sizes do appear to be small. Evidence for this comes mainly from monitoring Special Areas of Conservation designated under the EU Habitats Directive (European Commission, 1992), which typically fail to locate areas of suitable larval habitat containing abundant sea lamprey. These sites include the rivers Spey, Tay, Teith and Tweed (Gardiner & Stewart, 1995; Gardiner et al., 1995; Maitland & Lyle, 2000; APEM, 2002, 2004a, 2004b; Bull, 2004; Watt et al., 2008). Failure to detect larval sea lamprey may not necessarily reflect their absence though; it remains possible larval sea lamprey occupy deep water or mainstem habitats not targeted during electrofishing assessments.

Anecdotal evidence, gathered principally from fishery managers, points to general declines in sea lamprey spawning populations in a number of catchments, particularly in the north and west of Scotland. In the River Eachaig in Argyll sea lamprey were once considered common – so much so that the parasitic juveniles were viewed as a pest of coastal salmon nets, where they wounded valuable Atlantic salmon (*Salmo salar* L. 1758) (R. Teasdale, Eachaig Salmon Fishery Board, *pers. comm.*). Yet no larval sea lamprey were located in the Eachaig during the last nation-wide lamprey survey (ERA, 2017) and spawning adults have not been seen in recent years. This situation is paralleled on the River Lochy in Lochaber, where adults are no longer observed by local river managers, anglers or ghillies despite spawning activity being a historically common occurrence (J. Gibb, Lochy Association, *pers. comm.*). And while aggregations of spawning adults have been observed in the River Annan in the south-west of Scotland, these are limited to a short stretch of river below the Newbie Caul, and the total adult population is not thought not to be large (N. Chisholm, River Annan Trust, *pers. comm.*). However, the trend for adult sea lamprey abundance in the U.K. does appear to reflect a general increase in spawning migrants that may stem from ongoing improvements in water quality and access by adults to spawning habitat, or simply greater awareness of the species. And it should be noted that adult lampreys are not routinely surveyed, and therefore may be more common than presently believed.

European river lamprey are considered to have recovered significantly from population declines resulting from pollution in rivers throughout west-central Europe (Maitland et al., 2015). A generally high abundance of the species in some European states (e.g., Baltic Sea nations) appears to outweigh concern over local scarcity in some other regions (Maitland, 2000). In Scotland though, the population trends is considered to be 'Stable' (JNCC, 2013b). Most populations of the species are in the southern-central parts of the country, in particular around the Solway coast, Ayrshire and Clyde coasts as well as the Forth and Tweed areas, resulting in the most restricted range of the three Scottish lampreys. Further north, the species appears to be very scarce and north of the Great Glen found only in the rivers Shiel and Conon, although larval records have been identified from the rivers Glass and Peffery previously (ERA, 2017). National Biodiversity Network data identifies 310 1 x 1 km grid squares as being occupied by larval European river lamprey in the U.K. (JNCC, 2013b). Of these, 61 records (*c.* 20%) were located in Scotland.

The range of European brook lamprey largely overlaps that of the closely related European river lamprey, and the same is true in Scotland. It can be regarded as the most widespread and abundant of the three lamprey species present in the country. Records and survey data gathered during the previous national lamprey survey confirm the relatively high abundance of European brook lamprey compared with either of the other two species (ERA, 2017). As with European river lamprey though, uncertain larval identification makes assessments of status difficult throughout the country as records may be confused between both species (typically referred to as *Lampetra* spp. in surveys). It is present throughout Scotland, with the exception of Orkney and Shetland and the far northwest mainland. They are present but

apparently uncommon in the Hebrides, with only two populations identified in the Inner Hebrides and one in the Outer Hebrides. The presence of this species in the Hebrides is of significant interest, and the conservation value of the Skye population in the River Broadford has already been highlighted by Maitland & Lyle (1991). However, despite considerable survey effort in the Hebrides only two additional populations have been identified since then: one in the River Barvas on Lewis and one in the River Laggan on Islay (ERA, 2017). Interestingly, larval lamprey in the Barvas were found in substrates composed almost entirely of peat or coarse sand, something not yet observed elsewhere. It is likely that all three populations are relatively small, as a consequence of catchment size and limited availability of suitable larval rearing habitat. A U.K. wide assessment of the larval distribution of this species identified their presence in 1379 1 x 1 km grid squares (National Biodiversity Network), with 121 (*c.* 9%) in Scotland (JNCC, 2013c). The species' long term trend in Scotland is considered to be 'Stable'.

LEGISLATION PROTECTING LAMPREYS IN SCOTLAND

Several pieces of legislation protect lampreys in Scotland, including the preservation of important habitat features for larval, juvenile and adult life-stages, in addition to their protection from overexploitation (Tables 2 & 3). Although *P. marinus* does not receive direct protection through the Wildlife & Countryside Act 1981 (as amended), it is listed under Annex II of the EU Habitats Directive (European Commission, 1992) allowing for its inclusion as a qualifying feature within SACs. *Lampetra fluviatilis* is also listed under Annex II of the Habitats Directive, as well as Annex V. This latter legislative measure, as well as its inclusion in Schedule 3 of the Conservation Regulations (Anon, 1994) and Appendix III of the Bern Convention (Council of Europe, 1979) provides the means to restrict and regulate exploitation of *L. fluviatilis*. European river lamprey are fished commercially on a small scale in the U.K. (Masters et al., 2006), and more so in mainland Europe (Sjöberg, 2011), typically to provide bait for fishermen (Foulds & Lucas, 2008). *Petromyzon marinus* is listed under Appendix III of the Bern Convention, which also limits its exploitation. However, in Scotland it is not subject to the types of exploitation seen in France and the Iberian Peninsula, where targeted fisheries for the species exist (Beaulaton et al., 2008; Stratoudakis et al., 2016). *Lampetra planeri* is listed under Annex II of the Habitats Directive and Appendix III of the Bern Convention.

Scientific name	U.K. BAP	Habitats Directive Annex	Conservation Regulations Schedule	Bern Convention Appendix	IUCN Red List category (2015)
Petromyzon marinus	Y	II	n/a	III	LC
Lampetra fluviatilis	Y	II, V	3	III	LC
Lampetra planeri	N	II	n/a	III	LC

Abbreviations as follows: BAP, Biodiversity Action Plan; IUCN, International Union for Conservation of Nature.

Table 2. Summary of conservation legislation protecting lampreys in Scotland.

Legislation	Schedules and appendices
U.K. BAP	UK BAP priority fish species list
EC Habitats Directive	Annex II – designation as qualifying feature within SACs for the species listed. Annex IV – special protection for the species listed. Annex V – exploitation may be subject to management.
The Conservation (Natural Habitats etc.) Regulations 1994	Schedule 2 – European Protected Species in Great Britain. Schedule 3 – animals that may not be taken in certain ways.
Bern Convention (Convention on the Conservation of European Wildlife and Natural Habitats)	Appendix III – regulation of the exploitation of species listed.
IUCN Red Lists	CR – Critically Endangered. VU – Vulnerable. LC – Least Concern. EX – Extinct.

Abbreviations as follows: BAP, Biodiversity Action Plan; SAC, Special Areas of Conservation; EC, European Commission; IUCN, International Union for Conservation of Nature.

Table 3. Description of relevant conservation legislation schedules and appendices protecting lampreys in Scotland.

Both *P. marinus* and *L. fluviatilis* are listed as a priority species under the U.K. Biodiversity Action Plan (JNCC, 2007), indicative of their ecological importance and identification as requiring conservation. More recently, both species have been identified as a Priority Marine Feature (PMF) in Scottish territorial waters (Howson et al., 2012). This designation will help support advice concerning action affecting marine biodiversity, and assist with delivery of new marine planning and licensing systems as set out in the Marine (Scotland) Act 2010. It is noteworthy that some PMFs are being used to underpin the selection of Nature Conservation Marine Protection Areas in Scottish seas, which could protect foraging habitats and a prey base for these anadromous lampreys.

The distribution of lampreys in freshwaters of the U.K., particularly sea lamprey, is not reflected in the proportion of SACs identifying them as qualifying features of interest in Scotland; only four out of 23 of these sites aimed at protecting sea lamprey and their habitats (excluding the Solway Firth and Tweed estuary) are located in Scotland. Similarly, only four of 21 sites for European river lamprey (again excluding the Solway and Tweed estuaries) are located in Scotland. Fewer SACs include European brook lamprey (four in Scotland, out of 18 in the U.K.), and perhaps this reflects their greater and more widespread abundance. A review of all consents and licenses for discharge and abstractions affecting rivers in Scotland was recently completed, which will further prevent significant reductions in water quality and habitat access stresses on lampreys (Scottish Environmental Protection Agency, River Basin Management Plan 2015 - 2027). This publication outlines the means to protect and improve Scotland's water resources by reducing activities affecting notified features in designated sites (SACs), and includes a programme of measures to address them.

CONCLUSIONS & RECOMMENDATIONS

It is clear that lampreys are distributed broadly across Scotland, with the exception of Orkney, Shetland and the north-west mainland. Independent records (N = 910) of adult lampreys from 72 different river systems were collated and presented in this review. The European brook lamprey is the most commonly encountered species and it would appear that it has the best long-term prospects given it lacks large-scale migratory movements and can reside in relatively small headwaters, where it may be buffered from climate shifts and the introduction of invasive species. Both of these are highlighted as threats to lampreys in Scotland (JNCC, 2013 a, b, c). In-stream barriers can still isolate populations within certain river systems though, and we lack a good understanding of their water quantity and quality requirements (Maitland, 2003). European brook lamprey populations have evolved independently more than once throughout their European range, including in the U.K. (Espanhol *et al.*, 2007; Bracken *et al.*, 2015), and a high degree of genetic divergence exists between some populations elsewhere in Europe (Mateus *et al.*, 2013). Maitland (2004) and Maitland & Lyle (1991) highlight the presence and conservation value of "dwarf" European brook lamprey in the Scottish Hebrides. Data collected during the last national lamprey survey suggest that these very small lamprey represent part of a wider geographic variation in European brook lamprey size (ERA, 2017). It is not clear whether such phenotypic differences have a genetic basis or whether they reflect local adaptation to smaller, perhaps nutrient poor streams. In either case, the maintenance of phenotypic diversity is likely to require the species' preservation across the full range of river types and hydrological regions.

European river and sea lampreys undertake migratory movements between fluvial larval rearing habitats and juvenile foraging habitats in marine environments. This renders them susceptible to population reductions *via* habitat fragmentation caused by in-stream barriers. Although restoring connectivity between these habitats is a priority to SEPA under the Water Framework Directive (River Basin Management Plan 2015 – 2027) effective fishway technologies conducive to lamprey passage remain elusive. Evidence suggests European river lamprey, although readily attracted to technical fish passes, fail to pass in numbers sufficient to sustain populations (Foulds & Lucas, 2013; Tummers *et al.*, 2016; Silva *et al.*, 2017). Sea lamprey similarly suffer from poor passage efficiency when utilizing traditional fishway designs (Rooney et al., 2015; Castro-Santos et al., 2016; Pereira et al., 2017). Therefore, substantial improvements in this area must be realised before there is widespread adoption of technical fish passes as mitigation measures for these threats to migratory lampreys. There is strong evidence that providing access to spawning habitat through barrier removals will result in relatively rapid recolonization by migratory lampreys in areas where they were extirpated or restricted from (Hogg et al., 2013; Lasne et al., 2015; Magilligan et al., 2016).

New technologies, in particular the advent of environmental DNA (eDNA) as a tool for assessment, also presents an opportunity for the rapid and efficient (i.e., less costly) survey of rivers for the presence/absence of lampreys prior to and following management actions. Assays for sea lamprey have already been developed (Gustavson et al., 2015) and ongoing research seeks to establish methodologies to extend the capacity of eDNA to estimate their abundance. This new line of surveying technology represents a significant improvement over electrofishing surveys. However, currently it is not possible to distinguish between European river and brook lampreys using molecular genetics, rendering

the applicability of eDNA to the assessment of these species less useful.

Molecular evidence indicates that although genetic differences in sea lamprey populations do exist across large spatial scales (Rodriguez-Muñoz et al., 2004; Waldman, 2004), sea lamprey do not home to natal rivers (Bergstedt & Seelye, 1995) and individual river populations are not discrete. Therefore, it is probable that Scottish river catchments do not contain discrete sea lamprey genetic stocks as a result of constant exchange of adults. Whether Scottish regional populations exist (e.g., north vs. south) is unknown. As the Scottish metapopulation is unlikely to be large, a precautionary approach should be adopted and threats to all existing river populations identified and, where possible, reduced (JNCC, 2013a). The migratory behaviours of European river lamprey are not well understood, but anadromous populations in the U.K. do belong to a single panmictic population, sharing genes throughout their range (Bracken et al., 2015). As direct manipulation of lamprey populations *via* exploitation and stocking are largely absent, positive management for European river lamprey populations is likely to be generic - involving avoidance and mitigation of known threats (JNCC, 2013b; Maitland et al., 2015). The relatively restricted geographic range of the species in Scotland means that catchments supporting European river lamprey are often in close proximity to one another. As there is likely to be a high degree of gene flow between adjacent rivers, long term sustainability of stocks, especially in smaller rivers, may be partly dependent on immigration from proximal sites.

The designation of large Scottish river catchments like the Spey, Tay and Tweed as SACs where lampreys are a qualifying feature is consistent with the presence of abundant, high quality spawning and larval rearing habitat, and the potential for such habitat to support large populations. Additional sites could be identified by extending this approach to assessing the benefits of future management actions, such as barrier removal or bypass. The amount of suitable spawning and larval habitat made available could be quantified following the removal of in-stream barriers, or their mitigation with sufficient fishway installations. Priority could then be given to those actions that would maximize potential access to newly available habitat at the lowest cost (Jensen, 2017). For example, it has been suggested that weirs in the lower reaches of Scottish rivers may restrict lamprey access to large extents of these catchments (ERA, 2017), but passage efficiency has not been evaluated. Opportunities to ease passage at these locations might be viewed as a higher priority than removal of barriers on smaller systems, or higher up catchments where less suitable habitat would be made available following intervention. Prioritization based on catchment size could be fine-tuned where data on physical habitats exist in the form of remote sensing databases, aerial photographs or recent surveys, which could help identify the extent of key habitat features for lampreys.

Additional studies that examine contemporary *vs.* historical distributions, the relationship of spatial use in association with threats, and the efficacy of current and future assessment tools for lampreys will be extremely helpful in guiding management actions for all three species in Scotland. Populations that express atypical ecological traits (e.g. island populations of European brook lamprey; freshwater feeding European and sea lampreys) should be prioritized. Such populations are likely expressing local adaptions to environmental conditions, and their continued presence is a significant contribution to Scotland's natural heritage and biodiversity.

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SHORT NOTES

Overwintering of smooth and palmate newt larvae in the Gartcosh Nature Reserve, Scotland

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In temperate region amphibian communities, larvae that fail to complete metamorphosis by the end of the summer may remain in the ponds throughout the winter period. Metamorphosis occurs the following year (Werner, 1986; Griffiths, 1997). This is common in ponds characterized by higher altitudes, cooler temperatures and lower nutrient content (English Nature, 2001). The occurrence of overwintering as a strategy for amphibian larvae is widely acknowledged (e.g. Smith, 1951; Beebee & Griffiths, 2000; English Nature, 2001; O'Brien, 2016) but often unreferenced. There remains a paucity of records in the literature of UK, particularly of Scottish examples.

Overwintering in the UK has been shown to occur in the common frog (*Rana temporaria*) (Gadow, 1901; Archibald & Downie, 1996; Pintar, 2000; Bland, 2008; Walsh *et al.*, 2008). Common toads (*Bufo bufo*) were recorded to regularly overwinter in a pond in Yorkshire (Smith, 1951). Griffiths (1997) describes the potential of late cohorts of the three UK newt species to overwinter. *Triturus cristatus* (great crested newt) larvae are known to overwinter in water (English Nature, 2001) and several were observed in a garden pond, reportedly in poor condition (Atkins, 1998). Overwintering has been observed in *Lissotriton vulgaris* (smooth newt) larvae, indirectly (Smith, 1951) and directly (Bell Lawton, 1975; Cooke & Cooke, 1993). *L. helveticus* (palmate newt) larvae have been observed overwintering in Scottish ponds (O'Brien & Miro, 2016; P. Minting, pers. comm.).

The Gartcosh Nature Reserve (GNR), South Lanarkshire, is home to one of the largest known populations of *T. cristatus*, as well as significant numbers of *L. helveticus*, *L. vulgaris*, *R. temporaria* and *B. bufo* (McNeill, 2010). This site provided the opportunity to investigate whether overwintering was occurring across the five species. GNR is a purpose-built site, created in 2003, containing 24 ponds. The GNR is split across four areas: Bothlin Burn (BB, 8 ponds), Garnqueen Hill (GQH, 7 ponds), Railway Junction (RJ, 6 ponds) and Stepping Stone (SS, 3 ponds).

Over a period of three years from 2004 to 2006, 13,361 adult, sub-adult and metamorphic amphibians (Table 1) were translocated to the GNR from a 10 Ha site approximately 600m away, known as the Amphibian Conservation Area, part of the Gartcosh Steel Mill Industrial Site (McNeill, 2010; McNeill *et al.*, 2012). Due to the large number of toads caught, a portion were moved to the GNR outside the zones, which were originally encircled with amphibian proof fencing. SS was considered part of BB for translocation purposes.

As part of an investigation into the effectiveness of the translocation, larvae were sampled during the months of May to August 2006 (McNeill, 2010). A long-handled dip net (0.2m x 0.25m, mesh size 5mm) was used to make 2m long sweeps of 10 randomly selected points around the ponds' circumferences. A peak count of 41 GCN larvae (June) and 377 'Small' larvae (July) were caught (Table 2). 'Small' is used to refer to either *L. helveticus* or *L. vulgaris*, as it is not possible to distinguish between the two species in the field at this life history stage.

Area	GCN				Smooth	Palmate	Frog	Toad
	M	F	sa	juv				
BB	285	246	118	74	1233	1142	578	913
GQH	217	208	79	107	996	1086	325	727
RJ	27	29	135	69	571	477	597	719
GNR								809
Total	529	483	332	250	2800	2705	1500	3168

Table 1. Total number of amphibians translocated to the GNR zones from 2004-2006. M, male; F, female; sa, sub adults; juv, early juveniles. Only Great crested newts (GCN) were recorded by sex and stage.

Area	GCN	Small
BB	17	205
GQH	19	67
RJ	4	77
SS	1	28
Total	41	377

Table 2. Peak count of GCN and 'Small' larvae across the GNR zones.

This informed pond selection for the overwintering survey, with a subset of nine ponds sampled based on known larval presence. Sampling took place over two days on 6th and 7th January 2007. A long-handled dip net (0.2m x 0.25m, mesh size 5mm) was used to make 2m long sweeps of 50 randomly selected points around the ponds' circumferences. A further two ephemeral ponds (Eph) were included in the survey. These were swept only 20 times, reflecting the much smaller size. Snout-vent length (SVL) and body length (BL) in mm were recorded for all larvae, using calipers.

A total of 39 overwintering 'Small' larvae were captured during the two days of sampling (Table 3). No GCN larvae or other amphibian larvae were detected overwintering. 'Small' larvae were found in seven of the nine GNR ponds sampled and in one of the two ephemeral ponds. Smooth newt larvae metamorphose at approximately 30-45mm body length, palmate larvae between 25-40mm (O'Brien, 2016). Therefore, our overwintering larvae were within the size range where metamorphosis can occur in both species.

Causal factors in overwintering of amphibian larvae in temperate regions may include higher altitudes (as has been suggested for *T. cristatus* and *Rana aurora* (Californian red-legged frog): English Nature, 2001; Fellers *et al.*, 2001), lower water temperatures (all three UK newts and *R. temporaria*: Smith, 1951; English Nature, 2001; O'Brien, 2016; Walsh *et al.*, 2016), lower nutrient content/food availability (*T. cristatus* and *R. temporaria*: Pintar, 2000; English Nature, 2001; Walsh *et al.*, 2016), late oviposition (all three UK newts, *Tylotriton verrucosus* (Himalayan newt), *Rana ridibunda* (marsh frog), *R. clamitans* (green frog) and North American ranids: Bell & Lawton, 1975; Collins & Lewis, 1979; Werner, 1994; Kuzmin *et al.*, 1996; Griffiths, 1997; Ivanova, 2002) and high larval density (*Rana sphenocephala* (southern leopard frog), *R. catesbeiana* (North American bullfrog) and *R. clamitans*: Wilbur *et al.*, 1983; Werner, 1994). A further possibility could be exposure to sub-lethal levels of toxicants slowing rates of growth and increasing the time to reach metamorphosis (Carey & Bryant, 1995).

Protracted larval periods may lead to high overwintering larval mortality rates (Werner, 1994). Collins (1979) counters that remaining in the larval phase may allow growth in spring and autumn at times when metamorphs would be unable to grow, compensating for higher larval mortality rates. The elevated cost of overwintering is offset by metamorphosing into superior terrestrial conditions better suited for feeding and growth (Werner, 1986; Mitchell & Seymour, 2000) with a comparatively larger body size (Collins & Lewis, 1979; Verrell, 1985; Beebee & Griffiths, 2000; Denoel, 2016). Inclusion in the literature of additional occurrences of overwintering within the three newt species at a range of latitudes and altitudes across Scotland would be useful to further our understanding of this strategy and to consider the potential effect climate change may have on larval development.

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			BL (mm)		SVL (mm)	
Area	# Ponds	# Larvae	Mean	+/- SD	Mean	+/- SD
BB	3	22	36.1	3.2	16.4	1.3
GQH	2	2	39.7	3.1	17	1.1
RJ	1	10	32.5	4.2	14.7	1.5
SS	1	3	37.8	0.7	17.5	0.9
Eph	1	2	34.7	1.8	16.1	0.9
Total	8	39	35.4	3.8	16.02	1.6

Table 3. All overwintering larvae caught during sampling event in January 2007. BL, body length; SVL, snout vent length.

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An unknown 19th Century Clyde Herbarium

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A herbarium containing specimens collected circa 1855, mostly from the lower Clyde area, was recently advertised for auction (September 2016). The original owner was merely identified as 'Young', so the immediate thought was that it might be Morris Young, the first curator at Paisley Museum and Art Gallery (see Weddle, 2008 for an account of his 'Flora of Renfrewshire'). However, this possibility was quickly ruled out by examination of the handwriting on the labels, which did not match any of the hands involved in that manuscript, and by the lack of any specimens from the Paisley area.

A few days prior to the auction I went along to the saleroom with Keith Watson to view and photograph the labels and many of the sheets; this note describes the herbarium and discusses the possible identity of the collector (if owner and collector were in fact the same person).

The herbarium consists of about 186 loose sheets each with a printed 'EX HERBARIO Young' label at the top right (Fig. 1A); most also had a pre-printed label at the bottom right on which the botanical and common names for the specimen were written in copperplate along with the botanical family (though the label has 'Order') and the location and date of collection (Fig. 1B). There were additional sheets separating the herbarium sheets into families and labelled only with the family name. The specimens were prepared to quite a high standard and show many botanical features such as roots or tubers (K. Watson, pers. Comm).

The dates nearly all fall within the period May 9th to July 25th 1855; the exceptions are a specimen of lesser butterfly-orchid (*Habenaria bifolia*, i.e. *Platanthera bifolia*) from Toward Point in 1854, and an orange hawkweed (*Hieracium aurantiacum*, i.e. *Pilosella aurantiaca*) from 'banks of Clyde' in July 1856. It does seem possible that the date 'June 29th 1854' for the lesser butterfly-orchid should be 'June 29th 1855' as for the other specimens from Toward Point, though arguably the rarity of the species would justify a special visit.

Fig. 1. (A) Printed ownership label. (B) Example of a hand-written specimen label for *Hypericum hirsutum*, Hairy St John's-wort . (C) Example of a herbarium sheet: *Primula veris*, the Common cowslip.

The locations are centred on the area along and south of the Clyde to the east of Glasgow, though the collector also paid visits to Possil Marsh and the River Kelvin - unfortunately the exact location on the Kelvin is not given, but it is likely to have been in the Kelvingrove to Kelvinside area. There were also visits to Bute, Gourock, Dunoon and Toward Point, and to Castlecary Glen to collect herb-paris (*Paris quadrifolia*), which was known to occur there at the time, though unfortunately now no longer present. One location - 'Sligo's bank' - has not been found on maps of the time. As there are other sheets dated on the same day from the Cathcart and Cathkin area, it is likely to have been in that general area. We would be very grateful to hear from anyone who can shed any light on this.

Many of these locations, and the specimens found there, are reminiscent of some of the rarer specimens collected by William Mack, though the dates do not correspond – Mack's visits were a year or so later than Young's. However, it seems possible that Mack knew of Young's records, or perhaps more likely, they both consulted another Glasgow-based botanist such as William Gourlie (K. Watson, pers. comm.). However, though Hennedy in his Clydesdale Flora expresses his gratitude to Gourlie (Hennedy, 1865), there is no indication that Hennedy knew of Young's records – perhaps most significantly, he does not mention *Geranium phaeum* at Castlemilk or *Mertensia maritima* at Toward (K. Watson, pers. comm.).

A typical herbarium sheet (labelled 'Primula veris, Common Cowslip or Paigle') is shown in Fig. 1C. Keith Watson has identified the specimens on one or two sheets that lacked labels, and also corrected a number of erroneous identifications. Time did not permit detailed examination of all the specimens. Several specimens would need to be examined in more detail to verify their identities (K. Watson, pers. comm.).

Several of the Cowal specimens are of particular interest: *Botrychium lunaria* seems to be the earliest record in vc98 (Main Argyll); *Thalictrum flavum* confirms a couple of records from the same site, the only one in Argyll; and there are no localised early records of *Sherardia arvensis* in vc98, and none for any date in the NS 100km square (anonymous reviewer).

As to Young's identity, there are a number of possibilities. Having already ruled out Morris Young of Paisley, the next possibility is the William Young who joined the Natural History Society of Glasgow in 1863; nothing more has been discovered about his interests, but he lived in Maryhill (NHSG, 1863), so seems an unlikely candidate given the south Clyde focus of the collection. The only other Young with relevant specimens in the herbaria at Glasgow Museums is E. Young, but he appears to have been Edinburgh-based, and active some 17 years earlier (K. Watson, pers. comm.).

Another intriguing possibility is that it was James 'Paraffin' Young, who had strong connections with Glasgow, having been born in the East End and educated at Anderson's University (in later years he became President and benefactor of that institution). However, in the mid-1850s he was living at Polbeth, and his interests seem to have been focused on marketing shale-oil products from his factory in the Bathgate area, and in legal defence of his patents (Butt, 1963). He therefore seems an unlikely possibility, even though he is known to have had a keen interest in horticulture and later promoted botany classes (taught by Hennedy) at the Andersonian University (ibid.). Young also supported Hennedy's Flora financially (Hennedy, R. (1865)).

The herbarium records are now digitised and have been added to the Glasgow Museums Biological Record Centre database (Appendix 1). The data will also be submitted to the BSBI national database.

The herbarium was bought by a collector of 19th century herbaria in England (R. Sutcliffe, pers. comm.)

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Appendix 1. List of herbarium sheets (original spelling preserved). Specimens with no label were identified by Keith Watson; specimens re-identified (corrected) by him are marked with an asterisk; and a question mark denotes an uncertainty over the synonymy or that the specimen may have been wrongly identified. Current names are from the Botanical Society of the British Isles (BSBI) checklist.

Family	Current Name	Label Name	Common Name (on label)	Location	Date
Ophioglossaceae	Botrychium lunaria	Botryichium lunaria	Common moonwort	Toward Point	29/6/1855
Equisetaceae	Equisetum arvense	[no label]	[Field Horsetail]		
Osmundaceae	Osmunda regalis	Osmunda regalis	Common flowering fern	Toward Point	29/6/1855
Hymenophyllaceae	Hymenophyllum wilsonii	Hymenophyllum Wilsoni	Scottish filmy-fern	Gourock	9/6/1855
Aspleniaceae	Asplenium ruta-muraria	Asplenium Ruta muraria	Wall rue spleenwort	Cathcart bridge	2/7/1855
Blechnaceae	Blechnum spicant	Blechnum boreale	Northern hard-fern	Calder Wood	9/6/1855
Polypodiaceae	Polypodium vulgare	Polypodium vulgare	Common polypody	Castlecary	22/6/1855
Nymphaeaceae	Nymphaea alba	Nymphaea alba	Great white water-lily	Castlemilk	9/7/1855
Nymphaeaceae	Nuphar lutea	Nuphar lutea	Common yellow water-lilly	Possil canal	July 1855
Nartheciaceae	Narthecium ossifragum	[no label]	[Bog Asphodel]		
Melanthiaceae	Paris quadrifolia	Paris quadrifolia	Common herb paris	Castlecary	22/6/1855
Orchidaceae	Platanthera bifolia	Habenaria bifolia	Lesser butterfly orchis	Toward Point	29/6/1854
Orchidaceae	Dactylorhiza purpurella	Orchis latifolia	Marsh orchis	Gourock	9/6/1855
Orchidaceae	Orchis mascula	Orchis mascula	Early purple orchis	Gourock	9/6/1855
Iridaceae	Iris pseudacorus	Iris pseudacorus	Greater water iris or Corn flag	Castlemilk Glen	23/6/1855
Amaryllidaceae	Allium ursinum	Allium ursinum	Broad leaved garlic or Ramsons	Gourock	9/6/1855
Asparagaceae	Hyacinthoides non-scripta	Agraphis nutans	Wild hyacinth or Bluebell	Kenmuir Wood	26/5/1855
Araceae	Spirodela polyrhiza (?)	Lemna polyrhiza	Greater duckweed	Possil	16/6/1855
Araceae	Lemna minor	Lemna minor	Lesser duckweed	Possil	16/6/1855
Alismataceae	Alisma plantago-aquatica	Alisma plantago	Greater water-plantain	Loch Fadd Bute	14/7/1855
Juncaginaceae	Triglochin maritimum	Triglochin maritimum	Sea side arrow grass	Toward Point	29/6/1855
Potamogetonaceae	Potamogeton crispus (?)	Potamogeton crispus	Curly pond weed	Clyde	30/6/1855
Potamogetonaceae	Potamogeton natans	Potamogeton natans	Sharp fruited broad leaved pondweed	Possil canal	27/6/1855
Typhaceae	Sparganium erectum (agg?)	Sparganium ramosum	Branched bur-reed	Possil canal	25/6/1855
Juncaceae	Juncus squarrosus	Juncus squarrosus	Heath rush	Castlecary	22/6/1855
Juncaceae	Luzula sylvatica	Luzula sylvatica	great hairy wood-rush	Cambuslang	13/6/1855
Cyperaceae	Eriophorum angustifolium	Eriophorum angustifolium	Narrow leaved cotton grass	Possil	16/6/1855
Cyperaceae	Eleocharis palustris	Eleocharis palustris	Creeping spike rush	Toward Point	29/6/1855
Cyperaceae	Blysmus rufus	Blysmus rufus	Narrow leaved blysmus	Toward Point	29/6/1855
Cyperaceae	Carex paniculata (?)	Carex teretiuscula	Lesser panicled carex	Toward Point	29/6/1855

Cyperaceae	Carex echinata	Carex stellulata	Little prickly carex	Castlecary	22/6/1855
Cyperaceae	Carex viridula agg.	Carex flava	Yellow carex	Toward Point	29/6/1855
Cyperaceae	Carex hostiana	Carex fulva	Tawny carex	Toward Point	29/6/1855
Cyperaceae	Carex riparia (?)	Carex riparia	Great common carex	Kenmuir Wood	30/6/1855
Poaceae	Nardus stricta	Nardus stricta	Mat grass	Toward Point	29/6/1855
Poaceae	Puccinellia maritima	Poa maculata	Creeping sea meadow-grass	Toward Point	29/6/1855
Poaceae	Dactylis glomerata	Dactylis glomerata	Rough cock's-foot-grass	Kenmuir Wood	19/6/1855
Poaceae	Alopecurus geniculatus	Alopecurus geniculatus	Floating fox-tail-grass	Possil	16/06/1855
Poaceae	Alopecurus pratensis	Alopecurus pratensis	Meadow fox-tail-grass	Kenmuir Wood	19/6/1855
Poaceae	Anisantha sterilis	Bromus sterilis	Barren brome grass	Kenmuir Wood	19/6/1855
Papaveraceae	Glaucium flavum	Glaucium luteum	Yellow horned poppy	Toward Point	29/6/1855
Ranunculaceae	Caltha palustris	Caltha palustris	Common marsh marigold	Clydesdale bridge	19/5/1855
Ranunculaceae	Trollius europaeus	Trollius europoeus	Mountain globe flower	Kenmuir Wood	16/6/1855
Ranunculaceae	Anemone nemorosa	Anemone nemorosa	Wood anemone	Kenmuir Wood	19/5/1855
Ranunculaceae	Ranunculus aquatilis agg.	Ranunculus aquatilis	Common water crowfoot	Castlemilk pond	11/6/1855
Ranunculaceae	Ranunculus acris	Ranunculus acris	Upright meadow crowfoot	Carmyle	16/6/1855
Ranunculaceae	Ranunculus auricomus	Ranunculus auricomus	Wood crowfoot	Carmyle	26/5/1855
Ranunculaceae	Ranunculus bulbosus	Ranunculus bulbosus	Bulbous crowfoot	Morriston Cambuslan	26/5/1855
Ranunculaceae	Ranunculus ficaria	Ranunculus ficaria	Lesser celandine	Rose Bank Cambuslang	19/5/1855
Ranunculaceae	Ranunculus flammula	Ranunculus flammula	Lesser spearwort	Castlecary	22/6/1855
Ranunculaceae	Ranunculus fluitans (agg.)	Ranunculus fluitans	River crowfoot	Clyde	30/6/1855
Ranunculaceae	Ranunculus hederaceus	Ranunculus hederaceus	Ivy crowfoot	Gourock	9/6/1855
Ranunculaceae	Ranunculus lingua	Ranunculus lingua	Great spearwort	Possil	5/7/1855
Ranunculaceae	Ranunculus repens	Ranunculus repens	Creeping crowfoot	Dalmarnock	16/6/1855
Ranunculaceae	Ranunculus sardous	Ranunculus hirsutus	Pale hairy crowfoot	Possil	16/6/1855
Ranunculaceae	Thalictrum flavum	Thalictrum flavum	Common meadow rue	Toward Point	29/6/1855
Saxifragaceae	Chrysosplenium oppositifolium	Chrysosplenium oppositifolium	Common golden saxifrage	North bank of Kelvin	5/6/1855
Crassulaceae	Sedum acre	Sedum acre	Biting stonecrop	Toward Point	29/6/1855
Crassulaceae	Sedum anglicum	Sedum anglicum	English stonecrop	Toward Point	29/6/1855
Crassulaceae	Sedum villosum	Sedum villosum	Hairy stonecrop	Cathkin	23/6/1855
Rosaceae	Potentilla anserina	Potentilla anserina	Silver weed	Hamilton farm	11/6/1855
Rosaceae	Potentilla erecta	Potentilla tormentilla	Tormentil	Gourock	9/6/1855
Rosaceae	Comarum palustre	Comarium palustre	Purple marsh cinquefoil	Toward Point	29/6/1855
Rosaceae	Filipendula ulmaria	Spiraea Ulmaria	Meadow sweet	Paisley canal	7/7/1855
Rosaceae	Fragaria vesca	Fragaria vesca	Wood strawberry	Carmyle	26/5/1855
Rosaceae	Geum rivale	Geum rivale	Water avens	Kenmuir Wood	16/6/1855

Rosaceae	Geum urbanum	Geum urbanum	Common avens	Carmyle	16/6/1855
Rosaceae	Alchemilla vulgaris agg.	Alchemilla vulgaris	Common ladies mantle	North bank of Kelvin	5/6/1855
Plantaginaceae	Plantago lanceolata	Plantago lanceolata	Ribwort plantain	Carmyle	9/7/1855
Plantaginaceae	Plantago major	Plantago major	Greater plantain	Carmyle	4/7/1855
Plantaginaceae	Plantago maritima	Plantago maritima	Sea side plantain	Gourock	9/6/1855
Plantaginaceae	Digitalis purpurea	Digitalis purpurea	Purple foxglove	Ascog Bute	14/7/1855
Plantaginaceae	Veronica arvensis	Veronica arvensis	Wall speedwell	Dalmarnock	16/6/1855
Plantaginaceae	Veronica beccabunga	Veronica beccabunga	Brooklime	Cathcart	2/7/1855
Plantaginaceae	Veronica chamaedrys	Veronica chaemaedrys	Germander speedwell	North bank of Kelvin	5/6/1855
Plantaginaceae	Veronica montana	Veronica montana	Mountain speedwell	North bank of Kelvin	5/6/1855
Plantaginaceae	Veronica officinalis	Veronica officinalis	Common speedwell	Fereneze braes	7/7/1855
Plantaginaceae	Veronica scutellata	Veronica scutellata	Marsh speedwell	Possil Marsh	6/7/1855
Plantaginaceae	Veronica serpyllifolia	Veronica serpyllifolia	Thyme-leaved speedwell	North bank of Kelvin	5/6/1855
Plantaginaceae	Hippuris vulgaris	Hippuris vulgaris	Common mare's tail	Possil	16/6/1855
Lamiaceae	Stachys palustris*	Betonica officinalis	Wood betony	Dunoon	July 1855
Lamiaceae	Stachys sylvatica	Stachys sylvatica	Hedge woundwort	Cathcart	2/7/1855
Lamiaceae	Lamium album	Lamium album	White dead nettle	Hamilton farm	26/5/1855
Lamiaceae	Lamium purpureum	Lamium purpurium	Red dead nettle	Cathkin	23/6/1855
Lamiaceae	Ajuga reptans	Ajuga reptans	Common bugle	North bank of Kelvin	5/6/1855
Lamiaceae	Glechoma hederacea	Nepeta glechoma	Ground ivy	Hamilton road	19/5/1855
Lamiaceae	Prunella vulgaris	Prunella vulgaris	Common self heal	Toward Point	29/6/1855
Lamiaceae	Thymus polytrichus	Thymus serpyllum	Wild thyme	Toward Point	29/6/1855
Orobanchaceae	Euphrasia officinalis agg.	Euphrasia officinalis	Common eye-bright	Ascog Bute	14/7/1855
Orobanchaceae	Rhinanthus minor	Rhinanthus Crista-Galli	Common yellow-rattle	Toward Point	29/6/1855
Orobanchaceae	Pedicularis palustris	Pedicularis palustris	Marsh louse-wort	Fereneze braes	7/7/1855
Orobanchaceae	Pedicularis sylvatica	Pedicularis sylvatica	Pasture louse-wort	Gourock	9/6/1855
Lentibulariaceae	Pinguicula vulgaris	Pinguicula vulgaris	Common butterwort	Gourock	9/6/1855
Fabaceae	Vicia sepium	Vicia sepium	Bush vetch	Possil	16/6/1855
Fabaceae	Trifolium dubium (?)	Trifolium procumbens	Hop trefoil	Eastfield	12/6/1855
Fabaceae	Trifolium pratense	Trifolium pratense	Common purple clover	Carmyle	4/6/1855
Fabaceae	Trifolium repens	Trifolium repens	White trefoil or Dutch clover	Possil	16/6/1855
Polygalaceae	Polygala vulgaris	Polygala vulgaris	Common milk wort	Gourock	9/6/1855
Balsaminaceae	Impatiens noli-tangere	Impatiens noli-me-tangere	Yellow Balsam or touch me not	Castlemilk	Aug 1855
Primulaceae	Glaux maritima	Glaux maritima	Sea milkwort	Toward Point	29/6/1855
Primulaceae	Primula veris	Primula veris	Common cowslip or Paigle	Clydesdale bridge	19/5/1855
Primulaceae	Primula vulgaris	Primula vulgaris	Common primrose	Clydesdale bridge	19/5/1855

Primulaceae	Lysimachia nemorum	Lysimachia nemorum	Yellow pimpernel or Wood loose strife	Castlecary	22/6/1855
Primulaceae	Lysimachia thyrsiflora	Lysimachia thyrsiflora	Tufted loose strife	Possil canal	6/7/1855
Primulaceae	Anagallis arvensis	Anagallis arvensis	Poor man's weather glass	Cathcart	2/7/1855
Ericaceae	Calluna vulgaris	Calluna vulgaris	Common ling	Ascog Bute	14/7/1855
Ericaceae	Erica cinerea	Erica cineria	Fine leaved heath	Ascog Bute	14/7/1855
Ericaceae	Vaccinium myrtillus	Vaccinium myrtillus	Bilberry or Wortleberry	Gourock	9/6/1855
Plumbaginaceae	Armeria maritima	Armeria maritima	Common Thrift or sea-pink	Ascog Bute	14/7/1855
Polygonaceae	Polygonum amphibium	Polygonum amphibium	Amphibious persicaria	Paisley canal	7/7/1855
Polygonaceae	Polygonum persicaria	Polygonum persicaria	Spotted persicaria	Ascog Bute	14/7/1855
Polygonaceae	Polygonum aviculare	Polygonum aviculare	Common knot grass	Toward Point	29/6/1855
Polygonaceae	Rumex acetosa	Rumex acetosa	Common sorrel	Possil	16/6/1855
Droseraceae	Drosera rotundifolia	Drosera rotundifolia	Round leaved sun dew	Castlecary	22/6/1855
Caryophyllaceae	Moehringia trinervia	Arenaria trinervosa	Three nerved sandwort	Castlecary	22/6/1855
Caryophyllaceae	Honckenya peploides	Honckenya peploides	Ovate leaved sea purslane	Toward Point	29/6/1855
Caryophyllaceae	Stellaria uliginosa	Stellaria uliginosa	Bog stitchwort	Gourock	9/5/1855
Caryophyllaceae	Stellaria graminea	Stellaria graminea	Lesser stitchwort	Canal bank	27/6/1855
Caryophyllaceae	Stellaria holostea	Stellaria holostea	Greater stitchwort	North bank of Kelvin	5/6/1855
Caryophyllaceae	Stellaria media	Stellaria media	Common chickweed	North bank of Kelvin	5/6/1855
Caryophyllaceae	Stellaria nemorum	Stellaria nemorum	Wood stitchwort	Castlecary	22/6/1855
Caryophyllaceae	Stellaria palustris	Stellaria glauca	Glaucous marsh stitchwort	Possil	16/6/1855
Caryophyllaceae	Sagina nodosa	Sagina nodosa	Knotted pearl-wort	Ascog Bute	14/7/1855
Caryophyllaceae	Spergula arvensis	Spargula arvensis	Corn spurrey	Cathkin	2/7/1855
Caryophyllaceae	Spergularia marina	Spergularia marina	Sea-side sandwort-spurrey	Toward Point	29/6/1855
Caryophyllaceae	Silene dioica	Lychnis diurna	Red campion lychnis	Kenmuir Wood	26/5/1855
Caryophyllaceae	Lychnis flos-cuculi	Lychnis flos-cuculi	Meadow-lychnis or ragged robin	Kenmuir Wood	19/6/1855
Caryophyllaceae	Silene latifolia	Lychnis vespertina	White campion lychnis	Glasgow Green	17/6/1855
Caryophyllaceae	Silene maritima	Silene maritima	Sea campion	Toward Point	29/6/1855
Caryophyllaceae	Silene vulgaris	Silene inflata	Bladder campion	Carmyle	9/7/1855
Oxalidaceae	Oxalis acetosella	Oxalis acetosella	Wood sorrel	Daldowie	19/6/1855
Euphorbiaceae	Mercurialis perennis	Mercurialis perennis	Perennial or Dog's Mercury	Kenmuir	4/6/1855
Violaceae	Viola canina	Viola canina	Gerard's Dog violet	Carmyle	26/5/1855
Violaceae	Viola lutea	Viola lutea	Yellow mountain violet	Cathkin	11/6/1855
Violaceae	Viola tricolor	Viola tricolor	Pansy violet	West thorn	3/6/1855
Linaceae	Linum catharticum	Linum catharticum	Purging flax	Possil canal	25/6/1855
Hypericaceae	Hypericum hirsutum	Hypericum hirsutum	Hairy St John's-wort	Cathcart	10/7/1855

Hypericaceae	Hypericum maculatum subsp. obtusiusculum	Hypericum dubium	Imperforate St John's-wort	Bank of Kelvin	24/7/1855
Hypericaceae	Hypericum pulchrum	Hypericum pulchrum	Small upright St John's-wort	Loch Fadd Bute	14/7/1855
Hypericaceae	Hypericum tetrapterum	Hypericum quadrangulum	Square-stalked St John's-wort	Loch Fadd Bute	14/7/1855
Geraniaceae	Geranium dissectum	Geranium dissectum	Jagged-leaved crane's bill	Cathcart	2/7/1855
Geraniaceae	Geranium molle	Geranium molle	Dove's-foot crane's-bill	Possil	16/6/1855
Geraniaceae	Geranium phaeum	Geranium phoeum	Dusky crane's bill	Castlemilk	6/7/1855
Geraniaceae	Geranium sanguineum	Geranium sanguissimum	Bloody Crane's bill	Bank of Kelvin	24/7/1855
Onagraceae	Epilobium montanum	Epilobium montanum	Broad smooth leaved willow herb	Kenmuir Wood	19/6/1855
Onagraceae	Epilobium hirsutum*	Epilobium angustifolium	Rose-bay willow-herb	Dunoon	July 1855
Rubiaceae	Sherardia arvensis	Sherardia arvensis	Blue sherardia or Field madder	Toward Point	29/6/1855
Rubiaceae	Galium aparine	Galium aparine	Goose grass or cleavers	Dalmarnock	Aug 1855
Rubiaceae	Galium odoratum	Asperula oderata	Sweet woodruff	Castlemilk glen	1/6/1855
Rubiaceae	Galium palustre	Galium palustre	White water bedstraw	Possil Marsh	6/7/1855
Rubiaceae	Galium saxatile	Galium saxatile	Smooth heath bedstraw	Castlecary	22/6/1855
Rubiaceae	Galium verum	Galium verum	Yellow bedstraw	Dalmarnock	25/7/1855
Apocynaceae	Vinca minor	Vinca minor	Lesser periwinkle	Castlemilk wood	1/6/1855
Solanaceae	Solanum dulcamara	Solanum dulcamara	Woody nightshade	Barrhead	7/7/1855
Campanulaceae	Campanula rotundifolia	Campanula rotundifolia	Round leaved bell flower, hairbell	Loch Ascog Bute	14/7/1855
Campanulaceae	Jasione montana	Jasione montana	Annual sheep's bit	Loch Fadd Bute	14/7/1855
Menyanthaceae	Menyanthes trifoliata	Menyanthes trifoliata	Buckbean or marsh trefoil	Possil	16/6/1855
Asteraceae	Lapsana communis	Lapsana communis	Common nipple-wort	Castlemilk	Aug 1855
Asteraceae	Hypochaeris radicata	Hypochoeris radicata	Long-rooted cat's-ear	Toward Point	29/6/1855
Asteraceae	Tragopogon pratensis	Tragopogon pratensis	Yellow goat's beard	Cathcart	6/7/1855
Asteraceae	Crepis capillaris	Crepis virens	Smooth Hawk's-beard	Toward Point	29/6/1855
Asteraceae	Pilosella aurantiaca	Hieracium austriacum	Orange hawk-weed	Banks of Clyde	July 1856
Asteraceae	Pilosella officinarum	Hieracium pilosella	Common mouse-ear hawk-weed	Possil	16/6/1855
Asteraceae	Antennaria dioica	Antenaria dioica	Mountain everlasting	Gourock	9/6/1855
Asteraceae	Solidago virgaurea	[no label]	[Goldenrod]		
Asteraceae	Achillea millefolium	Achillea millefolium	Common yarrow or Milfoil	Cathkin	23/6/1855
Asteraceae	Achillea ptarmica	Achillea ptarmica	Sneeze-wort yarrow	Ascog Bute	14/7/1855

Asteraceae	Glebionis segetum	Chrysanthemum segetum	Corn marigold, Yellow ox-eye	Carmyle	4/6/1855
Asteraceae	Leucanthemum vulgare	Chrysanthemum leucanthemum	Great white ox-eye	Cathkin	23/6/1855
Asteraceae	Tripleurospermum inodorum	Matricaria inodora	Corn wild-chamomile	Carmyle	4/6/1855
Asteraceae	Senecio vulgaris	Senecio vulgaris	Common Groundsel	Dalmarnock	Aug 1855
Asteraceae	Doronicum pardalianches	Doronicum pardalianches	Great Leopard's bane	Carmyle	11/6/1855
Asteraceae	Tussilago farfara	Tussilago farfara	Colt's foot	Clydesdale bridge	19/5/1855
Asteraceae	Petasites hybridus	Petasites vulgaris	Common butter bur	Clydesdale bridge	19/5/1855
Caprifoliaceae	Valeriana officinalis	Valeriana officinalis	Great wild valerian	Toward Point	29/6/1855
Caprifoliaceae	Valeriana pyrenaica	Valeriana pyrenaica	Heart leaved valerian	Sligo's bank	2/6/1855
Araliaceae	Hydrocotyle vulgaris	Hydrocotyle vulgaris	Common white-rot	Toward Point	29/6/1855
Apiaceae	Sanicula europaea	Sanicula Europoea	Wood sanicle	Toward Point	29/6/1855
Apiaceae	Conopodium majus	Bunium flexuosum	Common earth nut	North bank of Kelvin	5/6/1855
Apiaceae	Conium maculatum	Conium maculatum	Common hemlock	Barrhead	7/7/1855
Apiaceae	Apium inundatum	Helosciadium inundatum	Least marsh wort	Loch Fadd Bute	14/7/1855
Boraginaceae	Symphytum officinale	Symphytum officinale	Common Comfrey	North bank of Kelvin	5/6/1855
Boraginaceae	Symphytum tuberosum	Symphytum tuberosum	Tuberous comfrey	North bank of Kelvin	5/6/1855
Boraginaceae	Mertensia maritima	Mertensia maritima	Sea-side smooth gromwell	Toward Point	29/6/1855
Boraginaceae	Myosotis arvensis	Myosotis arvensis	Field scorpion grass	North bank of Kelvin	5/6/1855
Boraginaceae	Myosotis scorpioides	Myosotis palustris	Creeping water scorpion grass [Forget-me-not]	Possil canal	27/6/1855
Boraginaceae	Myosotis secunda	Myosotis repens	Creeping water scorpion grass	Castlecary	22/6/1855

My family and other animals: mixed broods of great and blue tits in the Loch Lomond woodlands

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Every year, University of Glasgow ornithologists monitor breeding birds using the nearly 500 nestboxes installed in the forests surrounding the Scottish Centre for Ecology and the Natural Environment (SCENE, 56º 78 N 4º 36.8 W) (Jarrett *et al.*, 2017). This year (2017), we were intrigued to discover two instances of mixed great tit (*Parus major*) and blue tit (*Cyanistes caeruleus*) broods (Fig. 1). To the best of our knowledge, these are the first occurrences of mixed-species broods ever recorded at the site. Each was found in the Cashel area, and consisted of a great tit provisioned nest, occupied by multiple great tit chicks (five and six, respectively), and a single blue tit chick. Mean great tit brood size in Cashel was 6.7±0.4 (mean±S.E.). The two clutches hatched within one week of the population mean hatch date (population mean = 17/05; mixed broods = 19/05, 24/05), suggesting nothing unusual in their phenology. Chick mass on day 13 (hatch date = day 0) approximated the mean values recorded across the SCENE populations (Mixed brood blue tits = 11.2g, 11.7g; SCENE = 11.5±0.1. Mixed brood great tits = 17.9±0.2g, 18.7±0.4g; SCENE = 18.7±0.1). These figures, and the fact that all chicks in both broods fledged successfully, indicate that the burden imposed by an additional nest mate did not exceed the parent's provisioning capacity.

Two potential mechanisms can lead to such mixed species broods – nest takeovers, or interspecific brood parasitism. Nest takeovers are generally instigated by species larger than the current occupants (although blue tits have been known to oust larger pied flycatchers (Samplonius & Both, 2014)). Mixed-species broods can result if eggs from the original residents remain in the nest, and the new occupant lays without adding new nesting material. Alternatively, interspecific brood parasitism involves the dumping of eggs into another species' nest, leaving them to be cared for by the host. Interspecific brood parasitism can be obligate, as with the common cuckoo (*Cuculus canorus*), or facultative, where both parasitic and non-parasitic breeding strategies may be used, as is the case in blue tits (Lyon & Eadie, 1991). Mixed species broods are sufficiently rare that the conditions necessary to

Fig. 1. One of two mixed species broods found occupying nest boxes in the Cashel area during the 2017 breeding season. Heads of visible chicks are labelled by species; BT = blue tit, GT = great tit.

induce either mechanism are not well understood (Barrientos *et al.*, 2015). One possible factor, particularly relevant for cavity nesters such as great tits and blue tits, may be breeding density. In one of the few large scale studies to investigate this topic, incidences of great/blue tit mixed broods were found to increase with nest box occupation rate, suggesting that mixed-species broods can be a response to nest site shortage (Barrientos *et al.*, 2015). Interestingly, both mechanisms were observed in equal numbers, but only blue tits were associated with egg dumping, usually of a single egg. In 2017, Cashel had a relatively high nest box occupancy (81%), when compared with the two preceding years (2016 = 74%, 2015 = 73%). Also both incidences of mixed-species brood we report contained only one blue tit chick, with no unhatched eggs observed in either nest. As such, it appears quite likely that our first records of mixed-species broods resulted from facultative interspecific brood parasitism, motivated by limited nest site availability.

As a final point, we think it worth noting that mixed-species clutches/broods may be more common than records show. We, at least, and probably others, could easily have overlooked our blue tit interlopers. We often observe distinctly smaller eggs in great tit nests, which we had assumed were laid by the incubating great tits. Equally, had we only visited the nests before the plumage was sufficiently developed

to distinguish the two species, we may also have mistaken the blue tit chicks for great tit runts.

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On the paddling behaviour of a herring gull

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For some weeks (in September into November 2017) I had become aware that an adult herring gull, *Larus argentatus* (that was beginning to acquire its winter plumage) was, more often than not, to be seen on an area of irregularly-mown grass between the island's perimeter road and the rocky coast opposite my house (OS grid ref. NS171547). Casual observations revealed that it could be there come rain, wind or shine, often from daybreak to dusk largely oblivious of vehicular traffic, pedestrians walking along the adjacent pavement, dogs on leads or this observer sat watching from a park bench a few metres away (cf. Walker, 1949). I had originally thought that it might have something wrong with it but it was certainly able to fly away, as when a larger herring gull landed in its vicinity or it was very windy. It was present in the same area, irrespective of tidal conditions and opportunities for foraging on the nearby sandy beach or adjacent rocky shore. When not foraging on the grass it would sit atop a rocky promontory adjacent to the sward.

Even on quite a windy day, when standing-up it was almost constantly paddling the ground (Fig. 1) and pecking at the grass. Its paddling was most insistent, as it lifted each leg alternately, at a rate reported by Walker (1949) of 4 beats per second (confirmed here). It worked a small area of grass (sward height variously 3–7 cm) intently, stopping momentarily every so often and cocking its head to one side before head-darting after a revealed food item. It would then gradually shuffle its way backwards, creating a beaten track within the tarsus-high sward, paddling away as it went, sometimes turning in its track to recover items emerging within pecking distance. A successful peck rate of some 3 pecks per minute was recorded over a 15 minute period, with the identifiable items always being small earthworms (or perhaps fragments; note Barnard & Thompson, 1985). I never saw it pull an earthworm from its burrow in the manner of a blackbird (*Turdus merula*). Occasionally after a bout of vigorous paddling it would stretch a wing and leg out to one side. During calm weather, when another herring gull flew low over, it immediately ceased paddling and crouched down on the ground.

Fig. 1. Herring gull paddling the sward (Photograph: P. G. Moore).

In an attempt to mimic its paddling activity, I tapped the ground repeatedly, letting fall a cylinder of ash wood (3cm diameter, 214g weight) orientated vertically at a similar rate in the area the gull normally worked and was rewarded with an immature earthworm (10cm extended) of unidentified species within a minute. Adult herring gulls weigh substantially more: between 750–1250g.

Earthworms can be a major dietary item for herring gulls in meadows (Walker, 1949; Tinbergen, 1953, 1962), where large numbers have been reported participating in paddling. Given the success of this Cumbrae gull in foraging for earthworms, and their high energetic reward, it seems odd that this individual practised this habit alone. Herring gulls are normally gregarious, so other local gulls might have been expected to exploit the rewards betokened by this activity. I have noticed over the years, though, that herring gulls at different sites on the island seemingly have acquired different prey preferences; after a period of low water of spring tides, at one site there can regularly be found empty sea urchin tests (*Echinus esculentus*) on the pavement or perimeter road, at another the empty whelk shells (*Buccinum undatum*) that had been

occupied by hermit crabs (*Pagurus bernhardus*), after such items have been dropped from a height onto hard surfaces. It appears then that prey preferences in herring gulls can be very localised, even individual, within the confines of even a small island, with particular gulls adopting and maintaining a search image focused on a prey item that proves to be energetically profitable, available and accessible locally (see also Ellis *et al.*, 2012). In the case of the coastal individuals foraging on earthworms, the energy expenditure involved in extensive paddling must be quite considerable, but the caloric content of earthworms is high (Bolton & Phillipson, 1976; Barnard & Thompson, 1985). They clearly represent sufficient reward for this individual, resulting in its fixation on this, consistently available, food item.

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Developing skills for biological recording

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Since 2009, BRISC (Biological Recording in Scotland) and GNHS (Glasgow Natural History Society) have offered bursaries to improve skills related to biological recording in Scotland. Awards are for £200 or 75% of the course cost, whichever is lower. As part of the bursary project each person is asked to write an article for BRISC/GNHS newsletters; newsletters containing previous articles can be downloaded from www.brisc.org.uk/Newsletters.php .

Applications are currently assessed based on the following criteria:

- Contribution of records to recording schemes or other databases
- Sharing of skills and knowledge with others
- Whether the species or group is under-recorded, and records are sparse for the geographical area
- Whether the bursary is giving the applicant an opportunity they would not otherwise have

BRISC have provided two bursaries each year since 2009, and an anonymous donor has funded an additional course since 2012. GNHS (funded by the Blodwen Lloyd Binns Bequest) provided two courses until 2014; they now fund four each year. In 2011 and 2013 we provided an additional two bursaries of £100 to The Conservation Volunteer (TCV) apprentices. In 2017, SNH (Scottish Natural Heritage) made a contribution specifically aimed at those aged 25 or under; the remaining bursaries are open to any age. We have awarded a total of 57 bursaries over the last nine years. In some cases, bursaries were carried over to the following year due to cancellation of courses or the recipient being unable to attend.

Courses are generally provided by the Field Studies Council but are encouraged from any institution offering professional development courses. The following information summarises the applications from 2009 – 2017:

- More females than males applied for bursaries: an average of 18 per year compared to eight.
- The highest number of applications came from age class 26-40; followed by 18-25; 41-60; 60+
- The majority of applications came from both Edinburgh & Lothians and Strathclyde & Argyll (total 64 each). Following on, the highest number of applicants was from: Highland (33); Stirling & Perth (26); North East (21); Fife (10); Islands (7); Ayrshire (5); Dumfries and Galloway (4); Borders (3).

The profession of applicants is varied ranging from student/trainee, volunteers, unemployed or retired through to professional ecological consultant (Fig. 1).

There has been a total of 241 applications to the bursary scheme with the most in 2015 (69) and the fewest in 2010 (4). Overall, 57 bursaries have been awarded: a success rate of 24% for applicants.

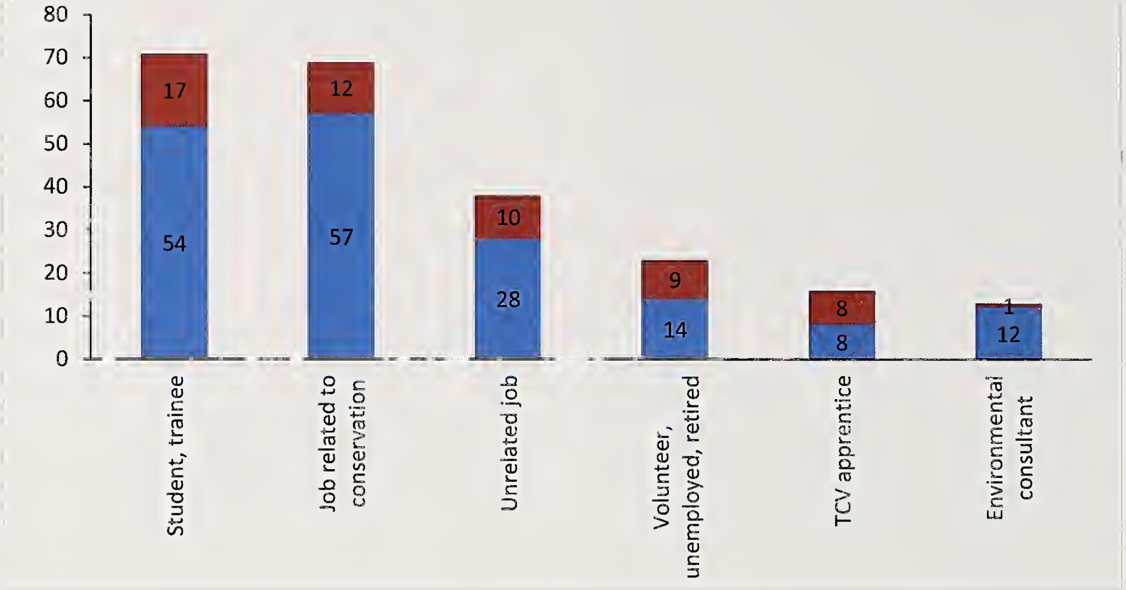

Fig. 1. Profession of applicants and those awarded a bursary (the full bar shows the total number of applicants with the top section showing number of bursaries awarded).

To summarise information relating to bursaries that have been awarded:

- A total of 38 bursaries have been awarded to women: 19 to men.
- The majority of bursaries were provided to those aged 26-40, followed by 41-60; 18-25; 60+
- Most bursaries were awarded to those living in Strathclyde & Argyll, followed by: Edinburgh & Lothians; Stirling & Perth; Highland; Islands; North East; Fife; Ayrshire; Dumfries and Galloway; none have been given in the Borders.

A variety of courses have been taken by bursary holders including mammal, plant, fungi and invertebrate identification and survey skills (Fig. 2).

In 2016, BRISC invited those who had been awarded a bursary to give a short talk at their conference. This was very successful, so the offer to speak has become part of the standard application process, along with offering free memberships for a year to BRISC and GNHS. BRISC and GNHS aim to continue this project into the future, as we consider it invaluable to improving the taxonomic skills of people in Scotland, particularly in geographic areas that are under-recorded, and focussing on species groups that are lacking in records and/or recorders. The application form is available on the BRISC website, with close of applications on 31 January each year: http://www.brisc.org.uk/Bursaries.php .

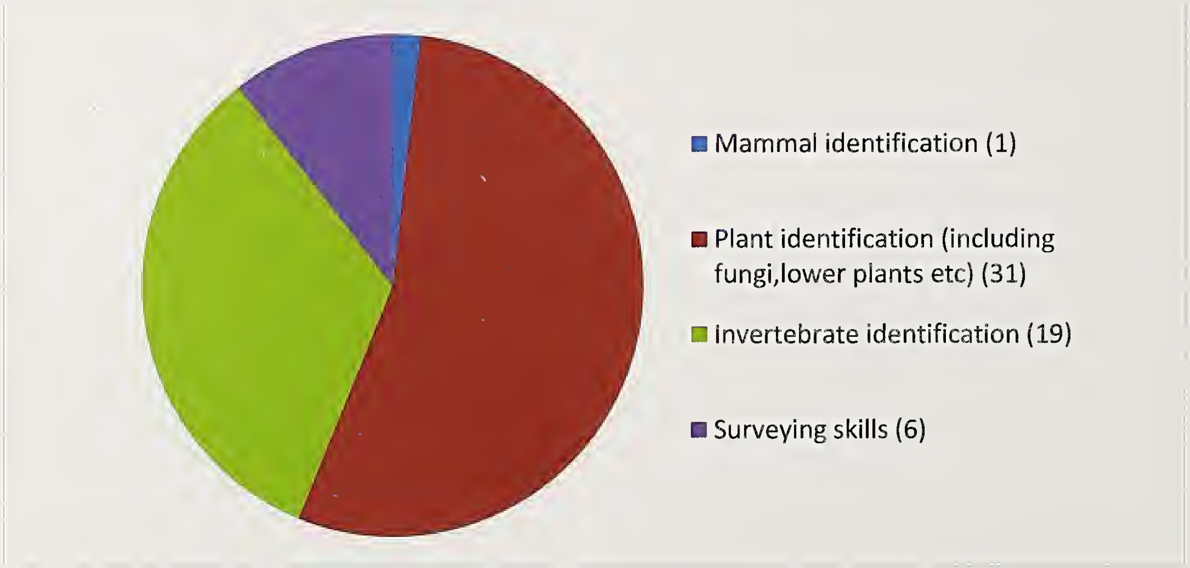

Fig. 2. Types of courses that 57 bursary holders have studied from 2009-2017.

First record of river lampreys (*Lampetra fluviatilis*) in the River Garnock, Ayrshire.

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The national survey of lampreys in Scotland (ERA, 2005) noted records of river lamprey *Lampetra fluviatilis* (L.) and sea lamprey *Petromyzon marinus* L. in 17 and nine river catchments respectively in south west Scotland, although the recent presence in some catchments remained uncertain. Migratory lampreys are of conservation interest and are regarded as an important indicator species in EU Water Framework Directive assessments of transitional waters, i.e. estuaries and reduced salinity sea lochs.

Records of lampreys in SEPA surveys of transitional waters are sparse (O'Reilly, 2000) and their occurrence there may best be inferred by observations in adjacent upstream freshwater bodies. This monitoring approach, collating records from river surveys and anecdotal observations of migratory lampreys, was adopted by SEPA in 2014 in a Citizen Science lamprey project in south west Scotland (O'Reilly *et al.*, 2016). The SEPA surveys in 2014 and review of anecdotal accounts highlighted the continued presence of sea lampreys in the River Leven, their recent occurrence in the River Clyde, a first record from the Black Cart, and first records of spawning sea lampreys in the Rivers Kelvin, Doon and Garnock. However, no new records of river lamprey came to light.

On 16th Sept 2016 electro-fishing was undertaken by SEPA on the River Garnock upstream of Dirrans Bridge (NS 30716 42342) near Kilwinning. The aim was to capture European eels *Anguilla anguilla* to assess their body burden of persistent organic pollutants. Sampling took place in a 50 m stretch of river between the pipeline/footbridge and the weir upstream. In addition to eels, there was a by-catch of around twenty good sized lampreys. Four eels and five lampreys were transferred to a holding container for closer examination (Fig. 1A). The lengths of the lampreys were measured as 29.5, 28.6, 32.0, 31.8, and 33.1 cm. Their size, oral disc tooth structure, dorsal fin separation and uniform coloration indicated that they were all river lampreys (Gardiner, 2003). The lampreys were returned to the river and one was subsequently photographed *in situ* attached to a stone (Fig. 1B).

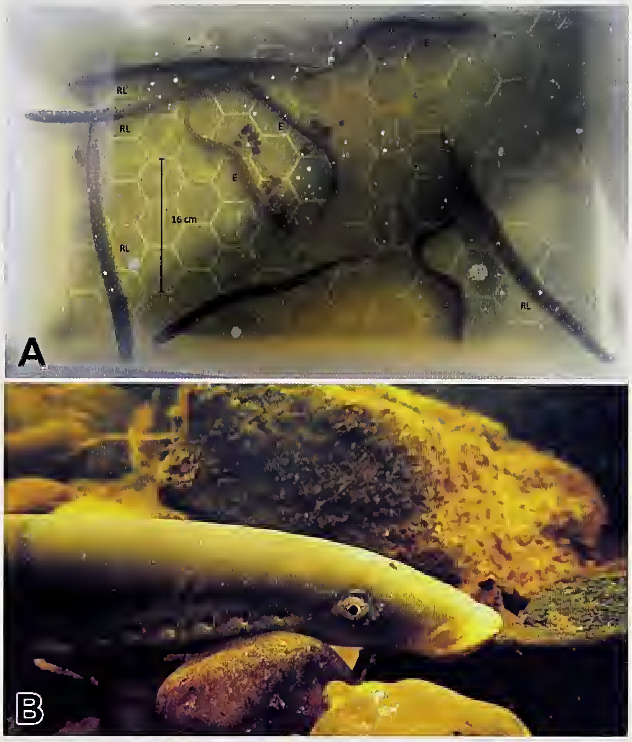

Fig. 1. (A) River lampreys (RL) *Lampetra fluviatilis* and European eels (E) *Anguilla anguilla* from the River Garnock in 2016. **(B)** A river lamprey *Lampetra fluviatilis* in the River Garnock in 2016.

Until recently only the non-migratory brook lamprey *Lampetra planeri* (Bloch) was known from the River Garnock. Both the river lamprey and the brook lamprey have been recorded from the nearby River Irvine. As the estuaries of the Garnock and Irvine merge as they enter Irvine Bay, it might be expected that migratory lampreys would enter both river systems. The sea lamprey was first recorded in the River Garnock by a local naturalist in 2012 and subsequently observed by SEPA in 2014. There have been no reports yet of sea lampreys in the River Irvine. The finding of river lampreys in the River Garnock in 2016 represents the first record from this catchment. It occurred at the same location, Dirrans Bridge, where sea lampreys were recorded in 2014 and it is possible that both species may spawn in this area. River lampreys migrate in the autumn, although spawning does not take place until the spring (Maitland, 2003). Weirs may act as barriers to lamprey migration (Nunn *et al.*, 2008). It is not certain if migratory lampreys can ascend the weir at Dirrans Bridge or if suitable spawning grounds occur further upstream.

A recent overview of the conservation of lampreys in Scotland is provided by Hume (2017) and cites south west Scotland as a stronghold for the river lamprey. However, their status in many rivers remains uncertain and it may be beneficial to target future surveys at potential lamprey spawning areas to

reveal important sites of value for conservation (Gardiner & Stewart, 1997).

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Revisiting the status of the toad (*Bufo bufo*) on Great Cumbrae Island

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Gibson (1976: 61) was emphatic: toads were completely absent from Great Cumbrae Island. Furthermore, McInerny & Minting (2016) show no post -2000 records of toads on the island. Recently, we received a Facebook posting (12 July 2017) from Millport resident Eddie Williams saying that he had found a toad under logs in his garden and furnished a photograph of same (which we have verified). Another resident Margaret Carson responded on-line that she also had seen a toad in her garden at Bute Terrace. Prompted by these records we sought further comments via social media and spoke to others on the island, particularly those who might have encountered toads as part of their usual outdoor occupations. Phil Lonsdale recounted on-line that toad spawn and tadpoles were "in their usual" sites in pools along the "Targets" (western coast) (see Fig. 1 for approximate locations). David Stevenson Sr. recounted that he had seen toads in the past among the footings of dry-stone walls around the golf course. Exactly how, and when, toads or toad spawn came to the island is open to conjecture but the species certainly seems well-established here now. William McIntyre (Breakough Farm), who informed me that he had seen toads on his farm, suggested that they may have been introduced – he thought perhaps twenty-or-so years ago – during re-stocking of rainbow trout in the reservoir at the golf course. They are, of course, common on the adjacent mainland. Although the Scottish Biodiversity List (2005) does not include common toads as a species of principal importance for conservation, Petrovan & Schmidt (2016) have provided evidence for long-term declines (since 1970) in this species both in the UK and Switzerland. New records, especially from an area previously thought not to include this species, are therefore very welcome.

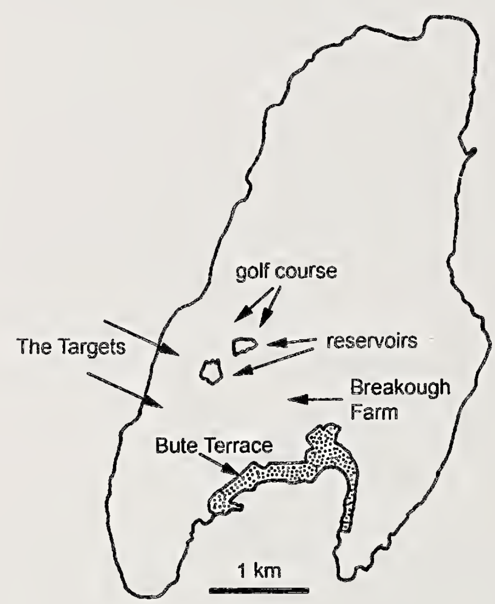

Fig. 1. Outline map of Great Cumbrae Island showing localities mentioned in the text. Millport town represented by stippled area.

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Giant Puffballs in Queen's Park, Glasgow

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The giant puffball (*Calvatia gigantea*) is one of our most spectacular species of fungi and the occasional occurrence of extremely large specimens may result in media news reports (BBC, 2004, 2016). It has a wide and scattered distribution in Scotland, with quite a few records in the east but rather few in the west (NBN, 2017). Around Glasgow it has been recorded at Carmunnock (1986) and at Lochwinnoch (2013) but until now has not been found in Glasgow itself.

On 14th August 2015 a local naturalist (John McOwat) reported the presence of unusually large puffballs in Queen's Park on the south side of Glasgow. Prompted by this report, the park was visited the same day by local members of the Clyde & Argyll Fungus Group (CAFG). The puffballs were found close to the main footpath just west of Camphill House. They were on bare ground with some leaf litter in a wooded area with lime and holly trees, and an under storey of privet bushes. There were seven puffballs, with three small ones, around 4cm in diameter, two of medium size, at 6 and 7cm diameter and two larger ones with largest diameters 12 and 15cm (Fig. 1). Unfortunately, by 18th August all the puffballs, except one at 7cm diameter, had been split open or broken into several pieces.

The site was revisited one week later on 25th August. The single surviving puffball (previously 7cm diameter) was still attached to the substratum (at NS 57626 62183) and intact with just some minor grazing damage by slugs. It was oval in shape and had now expanded in size with axis diameters of 23 x 19.5cm and a height of about 15cm (Fig. 2). Its large size, white colour, and characteristic leather-like surface texture allowed confirmation of its identity as the giant puffball, *Calvatia gigantea* (Fig. 3). Its size and colour made it quite conspicuous – looking like an old football lost in the park bushes.

Another week later, on 2nd September, the puffball had attained a size of 30 x 27 cm, but had become

Fig. 1. Two giant puffballs (diameters 12 and 15cm) in Queen's Park on Aug 14th 2015. (Photo - Jonathan Mitchell).

Fig. 2. The largest giant puffball (23cm wide) in Queen's Park on August 26th 2015, with 30cm ruler. (Photo - M. O'Reilly).

Fig. 3. The same giant puffball as in Fig. 2 showing leather-like texture and indentations from slug grazing. (Photo - M. O'Reilly).

detached and was rolling freely around and quite severely gouged by slug grazing (Fig. 4). A new group of three white puffballs (two whole but detached at 3 & 7.5cm diameter, and one smashed, perhaps around 10cm diameter) appeared on 9th September about 10 metres away (south) at the border of the bushes and the main path. However, these too were crushed or dislodged by the subsequent week.

Fig. 4. The largest giant puffball (around 30cm wide) in Queen's Park on 2nd Sept 2015, with 30cm ruler. (Photo - M. O'Reilly).

The following year, on 17th June 2016, two new giant puffballs were found in the same vicinity beside the base of a holly tree (NS 57625 62170) and were photographed *in situ* (Fig. 5). They had diameters of about 12 and 16cm but both were dislodged by the following day.

Fig. 5. Giant puffballs (12cm and 16cm diameter) in Queen's Park, June 2016. (Photo - Sheila Connelly).

The area was not revisited until 17th July 2017 when a single large white puffball (about 25cm wide) was observed at the base of the same holly tree. By 7th August 2017 the puffball (now 27.5cm x 26cm, and 15cm high) had detached and was rolling loose among the leaf litter (Fig. 6). The spent puffball had heavy damage from grazing slugs as well as numerous dead leaves and twigs adhering to its surface. Internally it had a yellowish spongy texture with an unpleasant smell, like a dead animal. Clouds of spores issued from the puffball when pressed indicating it had attained maturity.

It is evident from these records that a small colony of giant puffballs has become established in the park, but it seems to be difficult for such noticeable fungi to attain maturity in this location as the area is heavily infested with dogs, grey squirrels, and over-inquisitive children.

Fig. 6. Mature detached giant puffball around 27cm diameter, in Queen's Park, August 2017. (Photo - M. O'Reilly).

Glasgow's parks with their variety of broad-leaved and coniferous trees, their range of grassland and woodland habitats, and easy access from paths, offer ideal hunting grounds for fungus enthusiasts. The numerous parks in Glasgow have long been recognised for their fungal biodiversity and a handy guide to common fungi of the Glasgow's parks was produced over fifty years ago by Marshall (1952). Subsequently, field guides to help with identification of fungi became available for enthusiastic amateurs or students (e.g. Lange & Hora, 1963; Watling, 1973) and since then a multitude of superbly illustrated field, or photographic, guides to mushrooms and toadstools of Britain have been published (e.g. Phillips, 1981; Bon et al., 1987; Sterry & Hughes, 2009; Buczacki et al., 2012).

The new find of giant puffballs is the first record for Glasgow and highlights that, even in relatively well surveyed areas, new species can still be found. Many other new fungus species have been added to the Glasgow area in recent years by forays undertaken by CAFG.

Thanks are due to John McOwat and Richard Weddle (GNHS) for bringing this sighting to the attention of CAFG members and to CAFG members, Jonathan Mitchell and Sheila Connelly, for providing photographic images.

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New records of the White-banded Grapple-worm (*Melinna albicincta*) from marine waters in Western Scotland.

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Grapple-worms are tube-dwelling polychaetes with a serrated or scalloped dorsal skin flap (brim) and a distinctive pair of curved grapple-like hooks just behind the gills. The White-banded Grapple-worm, *Melinna albicincta*, is a relatively recently recognised species from Norway, Sweden, Novaya Zemlya and the Gulf of St.Lawrence (Mackie & Pleijel, 1995). It is distinguished from other species of grapple-worm by its serrated brim, strongly curved "grapple" hooks, the absence of a band of eyespots on the prostomium, and the distinctive white banding present on the inner gills (Fig. 1). The white banding is usually retained in specimens fixed in formalin and is best observed if illuminated from above rather than with transmitted light.

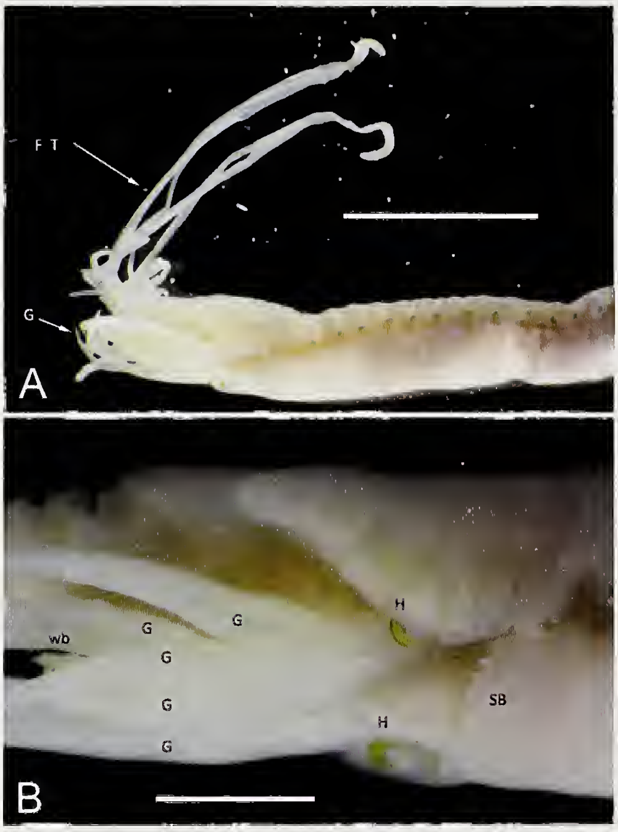

Fig. 1. White-banded Grapple-worm, Melinna albicincta. (A) Dorsal anterior view of a Loch Linnhe specimen showing feeding tentacles (FT) and gills (G). White banding on gills not visible in this specimen. Scalebar: 5 mm. (B) More magnified dorsal view of another Loch Linnhe specimen showing gills (G), grapple-hooks (H), and serrated brim (SB). Faint white-banding just visible on gills (wb). Scalebar: 1 mm.

Melinna albicincta was found for the first time in British waters in 2006 during a new SEPA survey in the Sound of Jura (O'Reilly & Nowacki, 2008). Of five sites sampled it was found at one site only, at 176m depth, around 10km east of the Small Isles, with ten *M. albicincta* collected between four 0.1m^2 Day Grab samples. The following year another 50 specimens were recovered from four more grabs at the same site. The worms produced conspicuous elongate tubes protruding from the sediment, which were ornately decorated with small shells and shell fragments. The Sound of Jura was subsequently sampled in 2008, 2009, 2010, 2013, and 2016. *Melinna albicincta* was found only at the one original site (10km east of the Small Isles) with eight, one, forty, zero, and ten worms recovered respectively, from a single Day Grab in each year and two grabs in 2016. Until recently, *M. albicincta* had not been recorded at any other locations in Scottish (or

British) waters. Hence this species, known from a single site in Scottish waters, could have been regarded as one of the rarest polychaetes in Scotland's coastal seas.

However, some investigative grab sampling by SEPA at six new sites in south Loch Linnhe in 2014 and 2015 revealed the presence of a number of *M. albicincta* at two sites and, in 2015, additional specimens were also collected in Loch Erisort, in the Isle of Lewis (Western Isles) (Table 1). The grapple-worms at all the new locations displayed the characteristic tubes decorated with shell fragments. The tubes are quite similar to that of another polychaete, the Shingle-worm *Owenia fusiformis* (see Koh *et al.*, 2003), which may occur at the same sites, though the shell fragments used by *M. albicincta* appear to be larger and less neatly arranged than those of *Owenia fusiformis*, allowing these two polychaete species to be distinguished by their tubes alone.

It is evident from these new records that *M. albicincta* is probably quite widely distributed on the west of coast of Scotland, even at relatively shallow depths. It is easily confused with *Melinna elizabethae*, which is also widespread in Scottish waters. The differences between these species are tabulated in some detail by Mackie & Pleijel (1995). The most obvious features distinguishing *M. elizabethae* is the presence of a band of eye spots on the prostomium and the absence of any white banding on the branchiae. The Loch Erisort specimens of *M. albicincta* were accompanied by 32 specimens of *Melinna palmata* collected in the same grab sample. *Melinna palmata* is a common species which has a brim with scalloped (not toothed) edges, smaller less curved "grapple" hooks and no white banding on the gills. It has plain accreted mud tubes without any shell fragment decoration.

A subsequent review of benthic faunal data submitted to SEPA by aquaculture licensees revealed some additional records of *M. albicincta* in the Sound of Barra, Little Loch Broom, and the Isle of Kerrera (see Table 2). These records have not been verified by SEPA. Specimens of a putative record of *M. albicincta* from Maol Bhan (Caol Mor), Isle of Skye, in 2014, were examined and found to be *M. palmata*. Careful examination of *Melinna* specimens is required to confirm further records of *M. albicincta* and delineate its true distribution in Scottish waters.

Location & Station	**Date**	**Lat. Long.**	**Depth (m)**	**No. worms**
Sound of Jura @ SJ1	2006-16	50° 50.507'N, 05° 46.829'W	174	119
Loch Linnhe @ GT 30	27/5/2014	56° 34.600'N, 05° 24.623'W	34.5	4
Loch Linnhe @ GT 73	27/5/2014	56° 40.893'N, 05° 15.848'W	21	1
Loch Linnhe @ GT 30	27/4/2015	56° 34.616'N, 05° 24.630'W	39	16
Loch Erisort @ Eilean Mor Lacasaidh	18/8/2015	58° 05.489'N, 06° 31.805'W	11	2

Table 1. SEPA locations for the occurrence of *Melinna albicincta*.

Location & Station	**Date**	**Lat. Long.**	**Depth (m)**	**No. worms**
Gighay, Sound of Barra	31/8/2010	57° 01.677'N, 07° 19.892'W	18	2
Ardessie, Little Loch Broom	19/9/2012	57° 51.960'N, 05° 18.803'W	36.3	1
Charlotte Bay (Rubh' Ard an Duine), Kerrera	16/6/2015	56° 25.184'N, 05° 32.003'W	22.9	1

Table 2. Additional unconfirmed records of *Melinna albicincta*.

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The Glasgow Naturalist (2018) Volume 26, Part 4, 98-100

BOOK REVIEWS

A Field Guide to Grasses, Sedges and Rushes

Dominic Price

Published by The Species Recovery Trust. 2016. Spiralbound; 72 pages, illustrated by colour photographs throughout. No ISBN number given. £11.99 through NHBS

I had actually purchased this book before I was asked to review it. Although I have been botanising for many years, grasses, sedges and rushes remain tricky and this sounded like a field guide I might even be able to carry! This has proved to be so and the book does indeed live up to its remit - ' to get the reader confident with all the regularly encountered graminoids'.

The first pages define the three main groups covered and contain a small glossary of graminoid plant parts. The next section lists species by habitat. The identification details are given of species most commonly found in six different habitats, e.g. 'neutral grassland' or 'woodland'. The species list page is faced in each case by a flow chart for that habitat leading the reader through the initial identification. This combination works well, particularly for the beginner. Extra species not on the most common list are given below, along with some good ecological information to help with identification.

The final sections illustrate and describe key features and habitat details of the 100 species covered by this book. The grasses are the best represented group, and I felt a few more sedges would have been useful. However, to select 100 species from over 300 must have been very difficult and there is a brief synopsis of some species not included.

To conclude, I do feel this is a book worth having, both for the beginner and also the many 'improvers'. For official recording it would need back-up from more detailed and specialist volumes, but this is often the case anyway. In my opinion, it fills a gap not only for field use, but also for learning and browsing. The presentation is innovative, interesting and attractive. Also, the photographic material is excellent. Undoubtedly, the author's extensive teaching experience has been put to very good use in the compiling and presentation of this volume.

Alison Moss

Birds of Europe, North Africa, and the Middle East: A Photographic Guide

Frédéric Jiguet and Aurélien Audevard.

Princeton University Press. 2017. 448 pages, paperback, colour photographs, colour maps, diagrams in black and white. ISBN-10: 0691172439. £24.95.

As someone who owns far, far too many books on birds, I have become very selective and (perhaps over-) critical of new publications. And I still prefer field guides that contain paintings or illustrations of birds to photographs, as I believe that in the hands of a highly skilled artist a single image can capture the essence of bird, which a single photograph can almost never do.

So, it was with some reluctance and scepticism that I came to review this book which attempts to help with the identification of all birds, both native and vagrants, in Europe, North Africa and the Middle East. This encompasses 860 species using 2,200 photographs, all in a paperback book 13 cm x 20 cm in size, of almost 450 pages, and weighing about 1 kg. So, very much intended to be portable and used as a field guide.

Having looked through the book for some time, I feel that at least some of my reluctance and scepticism is misplaced. For many species a useful photo (or photos) is used, each annotated with arrows highlighting important identification features. Adjacent is a limited amount of complementary text, summarizing identification features, voice, habitat and distribution, with a small map.

The identification features are in most cases reasonably up to date, and for many 'obvious' species, I feel that the amount of information provided will enable new observers to narrow down and identify bird species.

However, where identification is more challenging the book can be less helpful, the obvious example being the *Phylloscopus* and *Acrocephalus* warblers which have a long history of being difficult to identify. Much work has been done to dispel this problem, with some excellent publications produced to show that these birds are different from one another if seen well, and, when looked at with care (and calls heard), can be distinguished. This is where carefully produced illustrations by skillful artists are required. Instead, in this book, we have in some cases small and quite poor photographs which result in birds not looking different, and instead looking very

similar to each other; so, little help in identification. The limited text does supplement the images, but the photos are limiting.

Clearly, making a portable book, useful as a field guide, has resulted in size constraints, and the number of images that can be included. However, where this compromises help in the identification of bird species, the very essence of the book, this seems self-defeating.

So, my lasting impression of this publication is that is it is like the 'curate's egg': good in parts. If you wish to purchase a portable single book to use across Europe during your travels, and you prefer photos, this book will be of use for most species. But, if like me, you prefer illustrations, I would recommend one of the many other, very good, field guides instead.

Chris McInerny

The Amphibians and Reptiles of Scotland

Christopher J. McInerny and Peter J. Minting
Glasgow Natural History Society, Glasgow, 2016.
320 pages, paperback, numerous colour photographs and diagrams.
ISBN 978-0-9561126-8-2, £27.50 including post and packing. Order by email from Chris.McInerny@glasgow.ac.uk

Natural historians are likely to be well aware of the three successive *New Naturalist* books on the amphibians and reptiles of the British Isles (Smith, 1951; Frazer, 1983; Beebee and Griffiths, 2000) and may wonder about the need for a volume focussed on these animals in Scotland alone, where their diversity is somewhat less than in the rest of the country. I had my personal doubts, but should start this review by stating firmly that the authors have thoroughly quashed them.

The bulk of the book, about 240 pages, is devoted to individual accounts of each of the 16 species. If you wonder how there can be so many, one of the great values of the book is the full treatment it provides of the four marine turtle species recorded from Scottish waters and beaches. In addition to the well-established amphibian and reptile species, there are also accounts of the only non-native amphibian to have established populations in the wild (alpine newt), the sand lizard (deliberately introduced to Coll), and the grass snake whose presence/distribution in Scotland has been controversial. In addition to the species accounts, there is an extensive bibliography and a set of eight appendices covering topics such as legislation, good places to see the species, scientific names, exotic species and case studies of habitat management projects. In addition to McInerny and Minting, other authors have made valuable contributions, particularly Chris Cathrine on grass snakes, David O'Brien on newts and Ian Andrews for the many maps.

Each species account devotes about half of its pages to striking photographs of the animal, its life history stages and characteristic habitats. The text covers World range and taxonomy, identification of all stages (including variability), distribution across Scotland and by altitude, habitats, annual cycle, history of occurrence in Scotland, when and where to see, diet, population estimates, threats, protection, and gaps in current knowledge. A unique feature of this book is that common names are given in English, Scots and Scottish Gaelic. For most species, the distribution maps give records from 2000 onwards; the authors' intention is to highlight the areas with few records (which may result from under-recording, or a real lack of the species), in order to encourage more work. A possible disadvantage of this approach is that it does not allow an easy visualisation of trends before and after 2000. Certainly, a simple visual comparison between McInerny and Minting's maps with those in Beebee and Griffiths (2000), who present pre- and post 1970s records separately, shows some stark differences. I was surprised by the low numbers of records McInerny and Minting give for Ayrshire, Argyll and Bute, though less surprised by the low numbers recorded from the Highlands where lack of observers must be a big factor.

For me, one of the revelations of the book is the section on marine turtles. Previous *New Naturalist* books have included them, but usually very briefly. McInerny and Minting give records from the 19th century onwards and show that three species (loggerhead, Kemp's ridley, green) are essentially vagrants in Scottish waters, with small numbers of records, whereas leatherbacks are known to forage widely in the North Atlantic, including British waters, and should be considered a normal part of our marine fauna. The number of Scottish leatherback sightings at sea and on shore (nearly always dead turtles) is very substantial, preponderantly to the west, and sometimes well up estuaries and sea lochs. One possible omission: Smith (1951) gives two Scottish records for hawksbill turtles, not shown by McInerny and Minting.

Conservation is a re-current theme throughout. The two species of high conservation concern in Scotland are the natterjack toad and the great crested newt. Minting is an expert on natterjacks and the coverage of this species is especially authoritative and detailed. A puzzle remains: why is this species, so common and widely distributed on the western side of the European mainland, so restricted in the UK, and especially in Scotland, found only in and around a few coastal marshes in the eastern part of the Solway Firth? It is worrying that, although the area inhabited in Scotland has changed little since the 1990s, the numbers detected have fallen

considerably, despite well-considered conservation actions. The story for the great crested newt looks better. Although, as the authors note, this species is the fastest declining amphibian in the UK, comparison of their distribution map with that in Beebee and Griffiths (2000) shows more post-2000 recorded points and a wider distribution in Scotland. They mainly occur in three general areas : Dumfries and Galloway, the central belt and the Inverness region. Since great crested newts favour ponds in low lying areas, the sorts of places favoured by developers, there are no grounds for complacency. The saga of Gartcosh is a cautionary tale. Discovery of Scotland's largest great crested newt population there in an area planned for development led to a mass amphibian translocation to a specially created reserve nearby: now, as a consequence of some of the developments, the reserve is to be bisected by a road, with not easily predicted consequences for the newts.

Overall, the book is well written, easy to read and beautifully illustrated. The authors should be congratulated on the task they have completed in assembling vast, scattered sources of information, and I hope that the book will have the intended result of stimulating new observations to help fill the many gaps in our knowledge. McInerny's recent reports on Scottish reptiles demonstrate both what can be done and what needs to be done. Too many sections of the book include anecdotal, unreferenced information (references to overwintering by newt larvae are a case where I have personal interest) and more new research should be done to provide solid documentation, especially in the light of factors such as climate change.

I have two grumbles. First, none of the figures are numbered, nor referred to in the text. Often, this does not matter, but where a figure is placed some distance from the relevant text, as occurs with compilation figures (for example: on altitude distribution of eight species, placed after the frog chapter; and combined data on three of the marine turtles placed after the first of them), it does matter. Second, the bibliography is in sections, with an initial list of sources used throughout the book, then separate lists for each species chapter. I don't really see the advantage of this, compared to a single list. Moreover, having a 'bibliography' rather than a citation list can be quite problematic. As an example, O'Reilly *et al.*'s (2014) paper on 'star jelly' is on the common frog list, but is sadly not mentioned at all in the text, so we learn nothing about it.

These grumbles aside, the book is highly recommended. It is available free on-line, using the Glasgow Natural History Society's web-site, but I'm sure most enthusiasts will want their own copy.

Roger Downie

Solitary Bees

Naturalists' Handbook 33
Ecology and Identification Ted Benton
Pelagic publishing, Exeter, 2017, 208 pages
176 colour figures, 65 b&w figures
ISBN: 9781784270889
£19.99

Ted Benton was the author of the superb New Naturalist volume on Bumblebees. He has recently turned his attention to their far more numerous solitary cousins. His style as always is warm, engaging and authoritative. He has produced a highly accessible introduction to the natural history, ecology and conservation of the solitary bees. The book includes chapters on Diversity and recognition; Bee lives; Cuckoos in the nest; Bees and flowers; The conservation of solitary bees; Approaches to practical work; Keys to the genera of bees of the British Isles and References and further reading. The bee life cycles and pollination have the most in depth coverage. The information on bee biology is well supported by the author's own field observations and his photographs depicting behavioural sequences such as mating, collecting food and nest building.

The book claims to be aimed at sixth-form, undergraduate, postgraduate, field centre, ecological consultant, wildlife trust or conservation volunteers but has plenty of useful and interesting information to sustain the more experienced naturalist. It boasts a marvelously extensive and comprehensive reference list; making it an ideal stepping stone to more in depth studies.

Whilst the book does not profess to be a field guide it does include Colin Adam's key to genera (which incidentally is available free online from the BWARS website http://www.bwars.com/sites/www.bwars.com/files/diary_downloads/Britain%27s_Bees_Chapter_4_Keys_to_Genera.pdf) and offers tips on recognising some of the more common and distinctive of the 200+ British solitary bee species in the field. It does provide enough information and guidance to get an interested amateur starting to identify at least some of these bees. Benton wisely directs the readers who are more serious about identification to Falk and Lewington's superb Field Guide to the Bees of Great Britain and Ireland. The field guide, as one would expect, provides far more specific and comprehensive information on the British species and their distribution and also covers the ever popular bumblebees.

This text is a good way in for the uninitiated, those too intimidated by or not yet ready to commit the extra £15 or so for the Field Guide to the bees.

Jeanne Robinson

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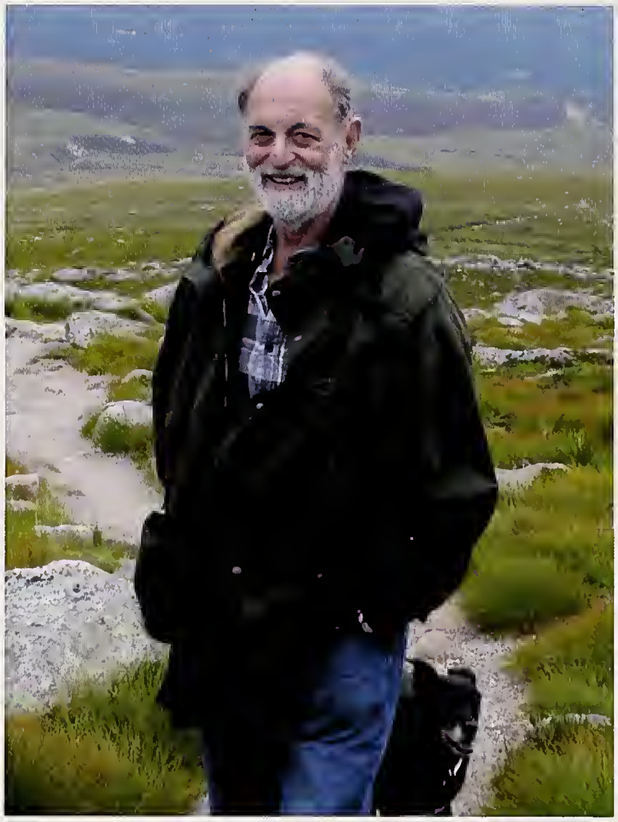
OBITUARY



Professor John Terry Knowler MIBiol PhD, 1942-2017.
Biochemist and Natural Historian

The distinguished Glasgow-based biological scientist, John Knowler, who died of pancreatic cancer on 24th October, soon after his 75th birthday, had a career in two distinct parts: first as a biochemist, and then, converting his childhood passion into a 'retirement' occupation, as a natural historian.

John's route into academic science was unconventional. He was a farmer's son, born near Faversham in Kent, and learned to love wildlife, especially birds, plants and insects, roaming his local countryside, especially the marshes. Having failed his 11 plus, he left school at 14 to work on the farm, but curiosity concerning the natural world took him back into education, first at Kent Farm Institute and then to Canterbury Technical College, where he took Zoology A level, and, just as important, met Penny, who became his wife in 1967. His early employment was as a technician in pesticide development, which allowed day release to study for Membership of the Institute of Biology, a degree level qualification. His excellence in Biochemistry led to an Industrial Fellowship paid by Pfizer's which allowed research towards a doctorate, supervised by Professor Martin Smellie at Glasgow University, and completed in 1972. John and Penny had just settled into the resultant post-doctoral research positions in the USA, when John was offered a lectureship in biochemistry back in Glasgow.

His time as a lecturer, later senior lecturer, was happy and productive, researching the influence of steroid hormones and other substances on gene expression, investigating molecules important in diabetes and Alzheimer's disease, and studying the mobilisation of starch in potatoes: a very wide range of topics. During this time, John enjoyed research abroad spells in Australia and the USA. He was an enthusiastic and able teacher of undergraduates, particularly in laboratories, and of postgraduates; he supervised 20 postgraduates, published many research papers and contributed to two editions of *The Biochemistry of Nucleic Acids* (a key text whose first edition was written by Glasgow's J.N. Davidson in 1950, three years before Watson and Crick's momentous discovery of DNA's structure). Postgraduates remember John's laboratory as a happy place: productive, with rigorous attention to detail, but also a lot of fun.

In 1990, John was appointed Professor of Biosciences and Head of the Department of Biological Sciences at Glasgow College (soon to be Glasgow Caledonian University), with a remit to improve research rankings and expand both research funding and staff and student numbers. These were all achieved, with the 1992 UK-wide Research Assessment Exercise grade of 1 (poor) raised to a very creditable 4 in 2001; staff increased from 22 to 43 and students from 211 to 760. In 1992, the growing department moved to brand new premises (the Charles Oakley Building) with custom-built teaching and research laboratories. Later re-branded as the School of Biological and Biomedical Sciences, under John's leadership it became one of the largest and most successful multidisciplinary biosciences units in the Scottish university sector. During this time, John turned up at all departmental seminars, no matter the subject, and was always first to ask a question, usually with a biochemical or molecular twist, sometimes to the discomfiture of the speaker! However, all this was achieved at a cost to his personal research output, which slowed to a trickle. Academic management can be a bruising business, and John decided to take early retirement in 2001 at age 59.

John had always kept up his early wildlife interests, with family holidays often to places where he could

increase his world list of birds personally seen in the wild (eventually over 6000 species). The most hair-raising was a near fatal shipwreck on a coral reef off Irian Jaya in New Guinea: the later sightings of Birds of Paradise were worth it! Retirement allowed John to make this private passion into a new occupation, albeit unpaid. He was appointed Honorary Professor of Ecology back in the University of Glasgow and devoted his time and energies to a range of projects and organisations, especially the Scottish Ornithologists Club (SOC), Butterfly Conservation and Glasgow Natural History Society (GNHS). He served a term as GNHS President (2005-7) and then as Vice-President (2008-10). During that time, he delivered tutorials on moths and a Presidential Address on the natural history of Spitzbergen. All this led to a new and distinctive list of publications mainly on the birds and insects of Scotland.

John had a long interest in ornithology, travelling much in Scotland, the rest of the UK and abroad to see birds. He contributed the chapter on the short-eared owl to the SOC's magnum opus *The Birds of Scotland* (2007), and he was in the exalted club of those fortunate enough to add a new bird species to the British List, the Barrow's goldeneye, which he found and identified at Irvine, Ayrshire in November 1979. John also had a wide interest in and knowledge of plants, particularly orchids, of which he had seen most British species. He was particularly proud of a wonderful colony of lesser twayblade near his home in Milngavie, which he showed to Anne and Simon Harrap, authors of *Orchids of Britain and Ireland*.

John's knowledge of moths, particularly macro-moths, was unsurpassed, and his interest in their larval foodplants was enhanced by his general botanical knowledge. From 2004, he was the official moth recorder for Watsonian vice-counties 86, 87 and 99, verifying, collating and analysing a huge amount of data, ultimately leading to his *Annotated Checklist of the Larger Moths of Stirlingshire, West Perthshire and Dunbartonshire* (2010) published by GNHS. This meticulous and inspiring work (143 pages) built on several of John's previous papers, including accounts of the moth assemblage of Flanders Moss (where he surveyed Rannoch brindled beauty, and argent and sable) and his confirmation of a Welsh clearwing population in the Trossachs. He also discovered a number of species new to the region such as alder moth and Blair's shoulder-knot. From 2009, John was identifier of the Rothamstead insect survey light trap at Rowardennan, a huge undertaking that resulted in significant contributions to our understanding of insect populations in the ancient woodland of east Lochlomondside. As well as finding new species, John was able to re-examine some of the older anomalous records. And he did not simply stick to moths; he co-authored papers on the Rowardennan nocturnal Ichneumonidae (2014) and caddis (2016) too. John also travelled throughout the British Isles in search of moths. His 'best moth trap ever' came as recently as August 2015 when, in unpromising conditions at Sandwich Bird Observatory, he trapped three very special migrants: bordered straw, orache moth and beautiful marbled.

John showed generosity with his entomological expertise in the museum sector. He volunteered on many collection-based projects latterly. In 2014, he assisted in cataloguing the British moths in the W.B.L. Manley collection held by Glasgow Museums; his expertise added considerably to the value of this collection. At the University of Glasgow's Hunterian Museum, 2015-17, he re-organised a large proportion of the British macro-moth collection, updating nomenclature, checking identifications, checking storage boxes, annotating variations and rarities, and extracting historical records for the national recording schemes. His work at the Hunterian inspired his co-authorship of a paper on the common wave, *Cabera pusaria* (2016). Even when very ill in August 2017, John began work on the most species- rich moth group, the Noctuidae, but sadly was unable to complete the task. In addition to all this work, John made the staff room a more interesting place with his colourful reminiscences of his innumerable natural history adventures. The attention to detail required for all this natural history work was a hallmark of John's approach. One prominent Scottish ornithologist rated John as 'the best all-round naturalist that I know'.

In addition to his interests in science, especially natural history, John was a skilled photographer and amateur painter. He was also devoted to his family, Penny and their two daughters, Clare and Sheila and his grandchildren, who survive him.

In 2012, John was diagnosed to be suffering from oesophageal cancer; an agonising year of chemotherapy and surgery followed, but he emerged, remarkably well, to carry on with his natural history work. Sadly, he was struck with pancreatic cancer in 2017. He was glad to be able to survive to celebrate his 50th wedding anniversary, his 75th birthday, and the award of Penny's PhD for research into a neurological disease of dogs, supervised by their daughter Clare.

Acknowledgements
John was a scientist with many interests, and several people contributed to this article through their knowledge of his various activities, especially Martin Culshaw, Penny Knowler, Chris McInerny, Jeanne Robinson and Iain Wilkie: thanks to them all.

Roger Downie
University of Glasgow and Glasgow Natural History Society

PhotoSCENE 2016-17

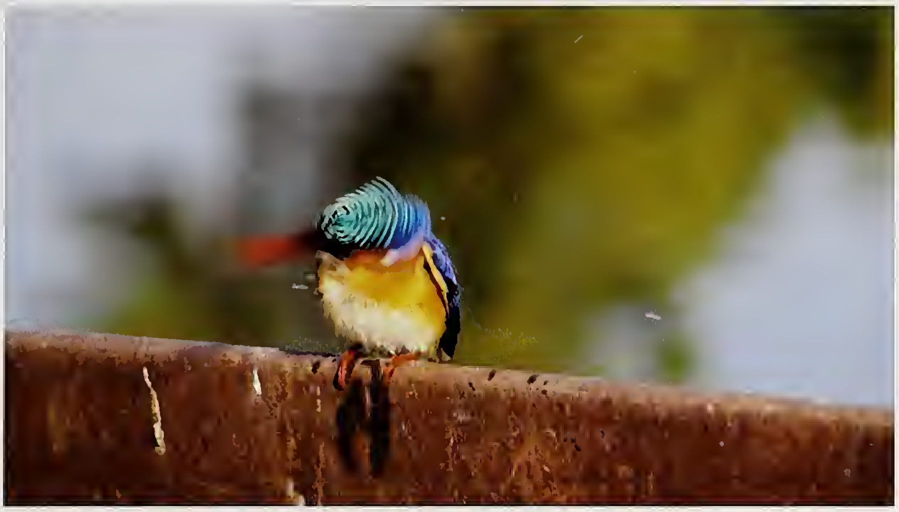
PhotoSCENE Natural History Photographic Competition

This competition is sponsored by Glasgow Natural History Society and the University of Glasgow's Institute of Biodiversity, Animal Health and Comparative Medicine. Its aims are to promote interest in Natural History and the work of SCENE (Scottish Centre for Ecology and the Natural Environment, the University's field station at Rowardennan), linkage between the Institute and the Society, and providing pictures for publicity. It was first setup in 2011. During this time, participation in the competition has increased, and prizes to the tune of £800 per year have been awarded at the Society's photographic nights each February. There were 117 entries from 30 entrants in 2016-17, with five shared first prize-winners (pictured below) and 6 second prizes awarded to; Christopher McInerny - Coralroot Orchid, Heather McDevitt - Sunset over the Dubh Loch, Barbara Helm - Angry bird (Blue tit), Ryan Carter - Loch Katrine, Robyn Womack - Forest mist, Suzanne Burgess - Green tiger beetle.

David Palmar

Anna Persson - Barracuda - taken in Egypt with Canon Powershot D30

Laura Allen - Logging - remains of tree in a heavily logged rainforest (Peru) taken with an Olympus TG-3 compact



Ken Ferguson - Malachite kingfisher on Lower Sabie Kruger NP July 2016 taken with Olympus 5 e-pen and 70-200mm lens

Darren Monkton - Frog spawn (Rana temporaria), Loch Arklet, Loch Lomond National Park, April 2015, Canon EOS 70D and Canon 100 mm Macro lens

Richard Thompson - Wildflower Identification - Ardnave, Isle of Islay, Remote Scotland Expedition, 22nd June 2015. Taken with Nikon D7000

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PROCEEDINGS 2016

The lecturer's name and the title of the lecture are given for each meeting as is the location within Glasgow University. All of the meetings were reasonably well attended with the joint lectures being very well attended.

January 12th
Two lectures: 'Glasgow's biodiversity: it's second nature' from Dave Garner and 'Roaming the seas: using mobile phone GPS tags to gain insights into the prospecting movements of immature Northern Gannets' from Jana Jeglinski. Boyd Orr Building.

February 9th
Photographic Night. Members' slides or digital slide shows, plus photographic competition results. Boyd Orr Building.

March 3rd
Joint lecture with Glasgow University Exploration Society: 'Glasgow University expeditions report back'. Graham Kerr Building.

March 8th
Lecture: 'Farming with wildlife' from Andrew Parsons. Boyd Orr Building.

March 15th
AGM followed by a lecture from Steve Campbell 'Close-up photography of nature: from phone camera to microscope lens'. Boyd Orr Building.

April 12th
Lecture: 'Insects and global warming' from Richard Thacker and 'The state of the apes' from Liz Williamson. Boyd Orr Building.

May 10th
Two lectures jointly with Hamilton NHS and Paisley NHS: 'Scottish ants' from Jeanne Robinson and 'Scotland's deep seas and their future in a changing ocean' from Murray Roberts. Boyd Orr Building.

June 14th
The Summer Social was held at The Cathedral House Hotel, Glasgow and was preceded by a guided tour of the necropolis

Excursions
17 day excursions and 1 weekend excursion were held throughout the year.

September 20th
Book Launch 'The Flora of Lanarkshire' introduced by Elspeth Lindsay and Keith Watson. Bower Building.

October 11th
Two lectures: 'Curious curator-curating the entomology collections at National Museums Scotland' from Ashleigh Whiffin, and 'Biodiversity offsets - a case study from Senegal' from Suzanne Livingstone. Boyd Orr Building.

October 26th
Blodwen Lloyd Binns Lecture: 'The modern natural history of naked snakes' from Mark Wilkinson. Graham Kerr Building.

November 8th
Book Launch 'The amphibians and reptiles of Scotland introduced by Pete Minting and Chris McInerny. Lecture from Amanda Malcolm 'Citizen Science in communities'. Boyd Orr Building.

November 24th
Joint lecture with Friends of Glasgow Botanic Gardens and Glasgow Tree Lovers: 'Dendrochronology in Scotland' from Anne Crone. Bower Building.

December 13th
Christmas Dinner followed by a lecture from Jim Coyle 'A review of Glasgow's local nature reserves'. Graham Kerr Building.

Officers and Council elected at the 2016 AGM
President
Roger Downie

Vice Presidents
Tony Payne
Bob Gray
Laura Allen

General Secretary
Mary Child

Assistant Secretary
Lyn Dunachie

Treasurer
Susan Futter

Winter Syllabus
Roger Downie

Social Secretary
Avril Walkinshaw

Excursions
Alison Moss and George Paterson

Membership Secretary
Richard Weddle

Librarian
Janet Palmar

Glasgow Naturalist Editors
Dominic McCafferty
Iain Wilkie

Newsletter Editor
David Palmar

University Liaison Officer
Barbara Mable

Section Convenors
Richard Weddle: Bio-recording
Alison Moss: Botany
Norman Storie: Ornithology
David Palmar: Photography
George Paterson: Zoology

Councillors
Chris McInerny
Ann Ainsworth
Sandra Hutchinson

BLB Executive
Secretary: Mary Child
Treasurer: Susan Futter
Scientific Advisors: Barbara Mable and Roger Downie
Technical advisor: Richard Weddle
Financial Advisor: Bob Gray

The Glasgow Naturalist

Advice to Contributors

1. The Glasgow Naturalist publishes articles, short notes and book reviews. All articles are peer reviewed by a minimum of two reviewers. The subject matter of articles and short notes should concern the natural history of Scotland in all its aspects, including historical treatments of natural historians. **Before submitting your article please read the detailed *Instructions for Authors* at:** http://www.glasgownaturalhistory.org.uk/gnat.html A summary of the instructions are given below.

2. Full papers should not normally exceed 20 printed pages. They should be headed by the title and author, postal and email address. Any references cited should be listed in alphabetical order under the heading References. All papers must contain a short abstract summarising the work. The text should normally be divided into sections with sub-headings such as Introduction, Methods, Results, Discussion and Acknowledgements.

3. Short notes should not normally exceed one page of A4 single-spaced. They should be headed by the title and author's name, postal and email address. Any references cited should be listed in alphabetical order under the heading References. There should be no other sub-headings. Any acknowledgements should be given as a sentence before the references. Short notes may cover, for example, new locations for a species, rediscoveries of old records, ringed birds recovered, occurrences known to be rare or unusual, interesting localities not usually visited by naturalists, and preliminary observations designed to stimulate more general interest.

4. References should be given in full according to the following style:

Pennie, I.D. (1951). Distribution of Capercaillie in Scotland. *Scottish Naturalist* 63, 4-17.

Wheeler, A. (1975). *Fishes of the World*. Ferndale Editions, London.

Grist, N.R. & Bell, E.J (1996). Enteroviruses. Pp. 381-90 In: Weatherall, D.J. (editor). *Oxford Textbook of Medicine*. Oxford University Press, Oxford.

5. An organism's genus and species should be given in italics when first mentioned. Thereafter the common name is only required. Please use lower case initial letters for all common names e.g. wood avens, blackbird; unless the common name includes a normally capitalised proper name e.g. Kemp's ridley turtle. The nomenclature of vascular plants should follow Stace, C.A. (1997). *The new Flora of the British Isles*, (Second Edition). Cambridge University Press, Cambridge. Normal rules of zoological nomenclature apply. When stating distribution, it may be appropriate to give information by vice-county.

6. All papers, including electronic versions, must be prepared on A4, double spaced throughout, with margins of 25mm, with 12 point Times New Roman font. Tables and the legends to figures should be typed separately and attached to the end of the manuscript. The Editor can make arrangements to have hand-written manuscripts typed if necessary.

7. Tables are numbered in arabic numerals e.g. Table 1. These should be double-spaced on separate sheets with a title and short explanatory paragraph underneath.

8. Line drawings and photographs are numbered in sequence in arabic numerals e.g. Fig. 1. If an illustration has more than one part, each should be identified as 9 (a), (b) etc. They should be supplied as a high resolution digital image or camera-ready for uniform reduction of one-half on A4 size paper. Line drawings should be drawn and fully labelled. A metric scale must be inserted in photomicrographs etc. Legends for illustrations should be typed on a separate sheet. Photographs are normally printed in black and white, however the Editor is able to accept a small number of high quality colour photographs for each issue.

9. If appropriate, Supplementary material can be published on the GNHS website along with the article. This option should only be used where it significantly adds to interpretation of data. This facility is not a data archive and therefore it is advised that publicly available databases for archiving data are used instead.

10. Articles should be submitted to the Editor by email (Iain.wilkie@glasgow.ac.uk) as a single word processed document. Photographs and illustrations should be high resolution with a minimum of 300 dpi in tif or jpeg format. Please contact the Editor if you require assistance with photographs as in some cases suitable photographs can be obtained.

11. When the article is accepted for publication, the author should return the corrected manuscript to the Editor as soon as possible. Final proofs should be returned to the Editor by email within 7 days. Alterations at this stage should be kept to the correction of typesetting errors. More extensive alterations may be charged to the author.

12. A copy of the published article will be sent to the first author as a pdf file. A paper copy of the article can be provided if requested.

13. All submissions are liable to assessment by the Editor for ethical considerations, and publication may be refused on the recommendation of the Editorial Committee.

14. From this point forward (Sept 2016) we will also request that Authors sign a publishing agreement giving The Glasgow Natural History Society the Copyright for articles published in The Glasgow Naturalist. This is standard procedure for publishing in most scientific journals today.